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DESIGN FOR DISASSEMBLY AND ENVIRONMENT

BY

ANDREW ABBOTT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

MANUFACTURING ENGINEERING

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1996

MASTER OF SCIENCE THESIS

OF

ANDREW ABBOTT

APPROVED

Thesis Committee

Major Professor

The image shows four handwritten signatures, each written over a horizontal line. From top to bottom, the signatures are: 1. Geoffrey Bookman, written in a cursive style. 2. LA Knight, written in a bold, blocky cursive style. 3. A signature that appears to be 'D. J. [unclear]', written in a cursive style. 4. Thomas J. Rockett, written in a cursive style.

DEAN OF THE GRADUATE SCHOOL

UNIVERSITY OF RHODE ISLAND

1996

Abstract

Government pressure, increased consumer awareness, and decreasing landfill space are affecting manufacturers. As product take-back becomes the norm, manufacturers will need tools to help them deal with end of life products.

Environmental policies are changing. Germany, Denmark, Sweden, and other countries are forming partnership strategies with manufacturers, aiming for resource management and eco-development. "Green" products and product reclamation are important parts of these programs.

Designing for disassembly can be profitable, but needs planning. Tools exist for determining economically optimized and environmentally optimized disassembly sequences for end of life products. However, there is a lack of a system that balances between a financial and environmental optimization. Such a sequence would be useful should government regulations come into existence which would financially penalize manufacturers for the amount of environmental pollutants they release or for companies that want to be environmentally friendly while at the same time fiscally sound.

The goal of the present work was to create an improved disassembly sequence optimization procedure. This new procedure will maximize environmental and financial returns. Suggestions for a factor correlating environmental damage units and monetary units are discussed.

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Chapter 1: Introduction

1.1 Background

The modern world is full of waste. Consumers and businesses purchase huge quantities of goods that are utilized to the end of their useful lives. More often than not, these products, large and small, are landfilled or incinerated. The end result is a massive loss of parts that can be reused, loss of materials that can be recycled, and waste that accumulates, polluting the environment and clogging landfills.

Landfill projections for the United States are bleak. The cost of landfilling materials is on the rise, and the space available for refuse is shrinking. Estimates from the Environmental Protection Agency predict that over 80% of existing landfills in the US will close within the next 20 years. Americans generate over 160 million tons of municipal solid waste per year, each person generating slightly over half a ton annually. It is a figure that is rising. Only 10% of the total solid waste is recycled [1].

Europe's most populous country, Germany, predicts that almost all of its viable landfill space will be used up in the next 10 years [2]. Landfill costs in 1992 were over 700% of their 1987 costs, and continue to rise [3]. Another problem Germany faces is a rapidly dwindling supply of natural resources.

Current “end-of-pipe” solutions for pollution control will soon not be enough. Most human activities use up or in some way damage the non-renewable resources of the planet. There is a limit to the amount of those resources. While many companies are willing to take action to correct visible, recognizable environmental harm (pollution, obvious waste in production processes), many are less willing to investigate more subtle, proactive environmental approaches.

This does not need to be the case, however. Systematic planning in the design stage of products can lead to products that are easy to disassemble for a profit and contain materials that can be reused or recycled. Even products not designed for ease of disassembly can be broken down economically and in an environmentally sound way. The most important goal of research into green design is to show that the ability to produce a product at a substantial profit and the ability to produce a product that is environmentally friendly need not be mutually exclusive.

Legislation at home and abroad is leaning toward mandatory recycling of many end of life products, most notably automobiles and large appliances, to help preserve and retain some of the value that is taken from the environment. In order to keep new products economically feasible and environmentally productive if faced with such legislation, designers will need a tool that shows them both the financial and environmental impacts of the products they design.

Planning for the end of life phase of a product while it is still under development can help lead to its being dealt with in a profitable and “green” manner.

Design for disassembly and environment (DFDE) provides a necessary tool for designers to do this type of planning. DFDE points out material recovery opportunities (MRO's) at an early design phase and allows designers to make any design changes needed to gain additional MRO's. An MRO is defined as a product, subassembly, part, or group of parts that can be either remanufactured and reused or recycled.

Interest in the fates of end of life products has grown lately in the research and business communities. Section 1.2 reviews some of the research work that has been done in this expanding field. Section 1.3 reviews some of the notable advances industry has made in the areas of recycling, material recovery, and green design.

1.2 Development of DFDE Tools

There has been a growing interest in disassembly theory over the past several years. Much work has been done on several different methods of disassembly sequence generation procedure, though most of it has neglected any environmental weighting considerations.

Many of the methodologies developed for disassembly design stemmed from the design for service (DFS) movement. Subramani and Dewhurst [4]

developed a system to generate disassembly sequences for product service tasks. This work allowed designers to evaluate the relative ease of common service tasks and help to plan for greater service efficiency. Many of the basic design philosophies of DFS are complimentary to and helped to develop design for disassembly (DFD).

Alting and Legarth [5] and Keoleian and Menerey [6] have conducted studies of Life-cycle Assessment (LCA) tools and methodologies. The LCA system was one of the first true environmental impact tools. Work to update and simplify LCA methods have been among the major concerns of researchers working in the design for environment (DFE) field. Methods of LCA will be discussed further in Chapter 2.

Gien and Kroll [7] of POGO International, developed DIANA, a software tool for documenting disassembly procedures and assigning times to each disassembly task. The software allows designers to quantify their designs for ease of disassembly using an extensive data-base of disassembly tasks and difficulties. The system focuses on specific areas of difficulty, but does not offer solutions for proper disassembly sequence, or financial or environmental gains from the disassembly process.

Navin-Chandra [8] developed ReStar, an analysis program for product take-back planning. ReStar is a CAD-based system stemming from the work of Subramani and Dewhurst [4]. ReStar uses spatial information coupled with a listing of the physical properties of each part to make a disassembly sequence.

Information about clearances and joint structures are recorded to allow a designer to recognize when a part can be removed or what steps are needed for the part's removal. ReStar uses a relational database of disassembly time calculations to optimize part removal.

Among Navin-Chandra's many other works in DFDE is ImSelection [9], a computer program that evaluates possible material choices for designs based on mechanical design constraints, material and manufacturing costs, and life-cycle environmental burden information. ImSelection is a knowledge-based rule system. The program helps designers consider possible material substitutions in designs that offer the same mechanical, physical, and cost properties while creating less of an impact on the environment.

Ishii, Marks, and Eubanks [10,11] expanded previous DFS models to include end of life disassembly and some environmental concerns. The group created a semantic network for describing part interaction which aided in the determination of disassembly sequences. They also developed the idea of material clumping, or the grouping together of materials that are either of the same material or will all be disposed of or reused. Clumping of materials negates the need for further breakdown in disassembly of the clump, lowering the disassembly costs and times.

The concept of clumping was further aided by the group's investigation into material compatibility. Materials that are easily recycled together were noted and the number of possible clumps were expanded. While the algorithms

developed by this team contained compatibility information that enhanced environmental issues, no environmental databases were included.

Lowe and Niku [12] of the California Polytechnic State University developed a disassembly rating system based on analysis of removal effort. Part removal was scored by determining force required to remove parts, accessibility difficulty, tools available, skill levels, and disengagement methods. Scoring could further be modified by different weighting factors for the importance of each removal category.

Johnson and Wang [13] created a system to analyze products for disassembly and material recovery opportunities. The system uses the Subramani and Dewhurst [4] automatic disassembly sequence generation method, and adds an optimization phase. This optimization is based upon a maximization of MRO's. The optimization, however, is only in financial terms and does not consider the environmental aspects of material recovery. The system also includes definitions of stopping points for disassembly.

Kalisvaart of TNO in the Netherlands [14] developed the MET point system for the measurement of environmental impact of the production and end of life phases of products. The MET system is a simplification of the LCA system. The method improves on LCA in more than just its ease of use; MET evaluations of products take much less time, do not require the assistance or opinions of experts, and produce results that are much easier to understand and use.

More recent and more important to the present work are two studies performed at the University of Rhode Island. Harjula [15] determined a disassembly sequence optimization method that dictates the proper disassembly sequence to maximize potential profit for consumer products. The system determines a predictive graph of disassembly cost or profit in dollars versus time of disassembly.

Rapoza [16] determined an environmentally focused disassembly sequence optimization method. The system uses the MET point evaluation method from TNO [14]. The system determines a predictive graph of environmental gains or losses in MET points versus time of disassembly.

The methods of Harjula and Rapoza will be discussed in greater detail in Chapter 3.

1.3 Green Design in Practice

What is a “green” design? The Office of Technology Assessment of the United States Congress defines green design as “a design process in which environmental attributes are treated as design objectives, rather than as constraints” [17]. In the design of “green” products emphasis is placed on all aspects of the product, from material acquisition to its final resting place. It is more than simply making sure the factory isn’t leaking toxic chemicals into the groundwater.

The concept of green design has been catching on in industry for several years now. Traditional design is mainly concerned with the aesthetic appearance, technical specifications, and, more recently, the manufacturability of new products. Green design mandates that designers consider environmental improvements in their creations. Many large and influential industry leaders have demonstrated their ability to put green design into practice, and many have turned a profit from these ventures. They have shown that a manufacturer can be both environmentally responsible and profitable at the same time, even creating further revenue simply by being green.

1.3.1 Automobile Recycling

The recycling of end of life automobiles in this country is not a new phenomenon. It is a well established, profitable venture, with over 12,000 used parts dealers and over 200 large scrap metal operations in the United States and Canada and multi-billions of dollars of annual revenue [18].

Cars that are "junked" by their last consumer owners are taken in by scrapping yards. The yards remove any components of value (useful engines, alternators, seats, dashboards, etc.) which are sold by auto parts recyclers. The vehicle hulk that is left over is put into a shredder, a large machine that chops the hulk into fist-sized pieces. These pieces are sorted by magnetic and other means to remove valuable ferrous and non-ferrous metals.

The remaining waste, about 25% of the original weight of the vehicle, is then shipped to its final resting place, often a landfill. This remaining portion, or fluff, is composed largely of assorted rubber, plastic, foam, and glass materials. It is often toxic, and, in the view of most automobile recyclers, not worth reclaiming. It is this fluff portion of shredder waste that current vehicle recycling efforts are aimed at [18].

There are currently few options for vehicle fluff. It can be simply landfilled; however, fluff often contains small amounts of highly toxic materials that require special and expensive treatment. Fluff can be incinerated to reclaim some of its value in generated energy. There are, however, concerns about toxic emissions from fluff burning. Homeowners adopt a "NIMBY" (Not In My Back Yard) attitude towards waste treatment facilities. Also, incineration is not an acceptable means of waste disposal in the eyes of most environmentalists, and it is often difficult to obtain permits to set up new locations for incinerators.

At this point in time, it is not technologically possible or economically feasible to completely identify and separate the growing plastic content of shredder fluff. The number of different plastics used is too high and the separation technology is not yet sophisticated enough to quickly and reliably separate it. The option exists to recycle the plastic content of shredder fluff into low grade co-mingled plastic. Co-mingled plastic presents several problems of its own. Over 100 different varieties of plastics are used in modern automobile construction, and the compatibility of the polymers found in fluff will be

questionable at best. The addition of compounds to increase the compatibility of the fluff mix is a must. Likewise, the properties of automobile fluff co-mingled plastics will be difficult to predict. Products made from co-mingled plastics will by their nature have varying properties.

There are efforts underway to reduce the problem of shredder waste. Realizing that potential environmental legislation could force auto makers to create more environmentally friendly vehicles, some manufacturers are planning ahead. In the United States, the Big Three auto makers (Ford, Chrysler, and General Motors) have joined forces to create the Vehicle Recycling Development Center (VRDC). The goal of the VRDC is to help the automobile manufacturers learn to design their vehicles for disassembly and recovery in order to close the production loop [19].

Located in Highland Park, Michigan, research workers at the VRDC video tape and time disassembly procedures on different automobiles, recording the weights and various other physical properties of parts removed. Three main divisions make up the VRDC- the disassembly and reprocessing group, the shredder residue reclamation group, and a group investigating material selection and recyclability design guidelines. Projects underway include: fluid removal and recycling, data collection and analysis, economic analysis, component collection and recycling, resin identification, seat and foam recycling, elastomer recycling, glass recycling, carpet and interior trim recycling, and instrument panel and bumper recycling [20].

Auto recycling in the United States is not mandated by law yet, but it could be. Automobile recycling is market based, following the philosophy that there can be no recycling without markets. By creating more environmentally friendly cars now, US auto makers hope to keep government involvement in auto design to a minimum. By providing recyclers with more and easier material recovery opportunities, environmental gains can be realized through profit motive, rather than command and control government legislation. As an example, the main instrument cluster from the dashboard of a 1996 General Motors C/K Truck can fetch \$200 as a resale part [21] for a minimal investment of time on the part of the dismantler (see Case Study, Chapter 4). The easier these parts are to access, the more likely they will be reused or recycled.

In Germany, where space for landfills is rapidly vanishing, the situation is much different. German law now states that many manufacturers are responsible for the end of life destinations of their products, as well as the packaging that those products were sold in. Strict new laws have automobile manufacturers scrambling to include DFD and DFE principles in the design of vehicles they intend to sell in Germany.

Manufacturers will be responsible for taking back and recycling end of life cars. By 2002, 85% by weight of retired vehicles must be reclaimed, either by recycling, reuse, or energy reclamation (only 5% of that total may be by energy reclamation). By 2015, that total raises to 95% by weight that must be reclaimed. The new laws mandate that all fluids, tires, batteries, air-conditioning

systems, air bags, catalysts, and other hazardous materials must be removed and dealt with before landfilling the rest fraction of the vehicle. Additionally, by 2002, all new vehicles to be sold in Germany may not contain any mercury, PVC, or lead (with the exception of car batteries), and other toxic items [22].

German car manufacturers have seen this eventuality and have been planning for it. BMW has set up an experimental vehicle disassembly plant to learn how to deal with the estimated 250,000 European BMW's that will be reaching end of life by the year 2000. Chapter 2 contains more detail of the German environmental legislation.

Cars such as the BMW Z1 are dismantled at the facility in accordance with the newly mandated laws. The Z1 is a sports coupe specifically designed for ease of disassembly. Its plastic body panels are designed to be removed from the metal chassis in under 20 minutes. BMW plans to transfer what they have learned from the Z1 and the disassembly facility to the rest of their product line [23].

Engineers at Volvo have adapted life cycle analysis (LCA) techniques and created the Environmental Priorities System to investigate the different environmental aspects of their vehicles. Designers can calculate an Environmental Load Unit total for a vehicle at any given stage of the design process to evaluate such things as material substitutions [24]. Volvo has also set up a test disassembly plant that will dismantle nearly 3,000 cars, mostly

Volvos, over a four year period to teach designers and dismantlers how to make dismantling green and profitable [25].

1.3.2 Computer and Business Equipment Recycling

The recycling of computers has been gaining more attention in recent years. Navin-Chandra states that for every three PC's bought, two become obsolete and predicts a one to one ratio of purchase and obsolescence by the year 2005 [26]. This will create a constant, steady stream of highly valuable waste.

More and more computers and related pieces of technical equipment entering the waste system present new problems and challenges. The influx of these end of life systems will bring about a tremendous new strain on the landfilling systems of the nation. The printed circuit boards in PC's are toxic parts, and must be disposed of in special, more expensive landfills. Should toxins ever leak from those pieces of discarded equipment, the manufacturers would be held responsible for the environmental damage and liable for its cleanup. Also, simply disposing of these systems wastes an enormous amount of potential profit. Modern computers contain many subassemblies and chips that can be removed and resold. Even circuit boards stripped of valuable chips can be processed for the precious metals they contain, especially older boards, which contain much more gold than the current state of the art. Some reused

parts are even more reliable than new parts. Computer memory, unless subjected to physical damage, can last virtually forever. While some new chips may fail during their initial testing, used memory has already passed that test, resulting in an extremely reliable product for resale [27] .

Some manufacturers have been practicing green design for years. Xerox is a manufacturer that has been taking back and refurbishing their copiers and other office equipment. Initially, many of the systems with reclaimable parts had to go through some sort of destructive disassembly in order to access those parts. These problem parts were gradually replaced with parts that facilitated easier removal and recycling, with valuable subassemblies being placed in more accessible spots and common parts, like plastic panels, being standardized for use in different products [28].

Five years ago, a true green manufacturing project was launched at Xerox, with an emphasis on cost savings. According to Jack Azar, Xerox's corporate manager for environmental design and resources conservation, "We demonstrated to our senior management that we could probably do it very cost effectively and increase our productivity in the process." While Xerox's previous efforts at reuse of parts had been saving the company \$200 million dollars a year, green design reuse rates went to \$250 million a year. Total cost savings due to green design efforts, including DFD, remanufacture, and recycling is estimated at \$500 million a year [29].

AT&T has also recycled and reused many of its products. Before the split-up of the telecommunications giant in the 1980's, most phones in the United States were leased from the company. Old phones were taken back, broken into their components, and the electronics reused whenever possible. After the break-up, most Americans started buying their phones, vastly cutting down on reuse. Green design at AT&T has increased in recent years with such projects as the "green telephone." The goal of these projects is to minimize the environmental impact of a prototype phone throughout its life cycle [29, 30].

Many other companies have taken up the challenge of designing environmentally sound products. The IBM PS/2, Hewlett-Packard Desk-Jet and workstations, the Kodak Funsaver camera line and many others are all designs that demonstrate that green design can be profitable and have limited environmental impact.

1.4 Justification of Study

Manufacturing uses resources. Many of these resources, once discarded, are not renewable. All of the resources used by manufacturing are, in one form or another, taken from the Earth. The Earth does not have an unlimited supply of resources for manufacturing to use nor will its ecosystems last forever against the pollution and waste it can produce. Humans use fossil fuels at a rate that the planet could never keep up with. Forests cannot grow back faster than

industry can cut them down. Enough landfill space does not exist that people can fill. Living systems inevitably fail due to buildups of toxic wastes.

It is conceivable there will come a time when mankind's progression of technology and production will directly and negatively affect the health and well-being of all life on the planet. Man has demonstrated a tremendous effect on the planet in only the last hundred years, and his influence is growing faster as time goes by.

Many of the materials mankind transforms into finished goods do not have a lifetime limited to that of the product itself. The steel of a junked car can live on in the body of a new automobile. Plastic polymers can be ground and re-pelletized to serve as feed-stock for other plastic goods. Motors, engines, computer memory and countless other products can be removed from discarded goods to be reused in other products, and are often more reliable than a new part.

Designers have the capacity to slow the need for further resources from the Earth and stem the flood of waste into the over-burdened landfill system. It is possible to design new goods that will function and then be dealt with in a closed loop manner, with their components going on to find uses in other goods.

Total closed loop design may not be possible, but with the proper tools, designers can judge how close their efforts can get to that goal. DFD tools do not consider both the environmental and financial aspects of disassembly.

Analysis tools such as LCA methods are extremely tedious and time consuming,

requiring the effort of experts to perform and interpret. These methods do not provide designers with an easy to use, quick way to determine the financial and environmental impacts of their designs.

DFDE analysis will give a clearer picture of the end of life effects of manufactured goods, and point out possible areas for improvement in new designs. Using sound design techniques and planning for material recovery opportunities, engineers can use new technologies and products to create a balanced, sustainable future for industry.

1.5 Report Structure

Chapter 2 will discuss some of the legislation driving world DFDE research, as well as the underlying philosophies behind the laws. LCA methods and the MET point system will be discussed in further detail.

Chapter 3 discusses the DFDE financial/environmental optimal disassembly sequence generation procedure. Analysis assumptions will be justified. Financial/environmental line improvement will be discussed.

Chapter 4 presents the case studies analyzed for this work. Observations will be made of the collected data, and the relationship between the products and the results generated will be discussed.

Chapter 5 draws general conclusions about the project. Suggestions for future work will be discussed.

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Chapter 2: Literature Review

Chapter 2 explores some of the background issues leading to and requiring design for disassembly and environment. First, environmental philosophies will be discussed to give a clearer understanding of the review of world environmental legislation that follows. An explanation of life cycle analysis (LCA) is given, along with a discussions of its merits and weaknesses. The MET point system, a simplification of LCA evaluation methods, is introduced. Material recovery opportunities are defined and demonstrated. Finally, conclusions are drawn from the material presented in the chapter.

2.1 Environmental Philosophy

Several schools of thought have developed with regard to the aims of green design. One's philosophical viewpoint of the process greatly determines the ends of the process. Paradigms range from "environmentally unconscious" to extreme environmental protection. The goals of the top management of each individual manufacturer will fall somewhere between the two, and will help to mold the DFDE policies designers will be asked to adhere to.

Conflict arises between industry and "society" when their perceived aims are different. Industry tends to view environmentalism as an economic liability, and is slow to adapt measures that will affect the bottom line of corporate profit.

The views of the public are often less concerned with financial impacts and more with detrimental effects to the environment, risks to human health, and large decreases in animal populations. Companies that can capitalize on the environmentally friendly attitudes of their customers stand to gain a larger share of the market they are competing for. The ideal is a company that can provide a product of equal function to a competitor that is designed for the environment and can do so at no cost penalty or at a lower cost.

The three branches of ecological thought investigated in this paper are environmental protection, resource management, and eco-development. They show widely different views of the role of humans and human development in the environment, but are at the heart of world legislative agendas [1].

2.1.1 Environmental Protection

Environmental protection views the environment as an economic externality (something usually considered outside the scope of the process, yet still influenced by that process) that is determined and protected by law.

Environmental protection is a largely anthropocentric (human centered) view of the world. "Environment" is generally limited to factors that directly effect people. Effects of industrial development and pollution are gauged by how they influence human health and welfare. This view does not consider sustainability of resources and a closed-loop system for production, but rather that there is a

fairly unlimited supply of resources to draw upon with little effect on the human population.

Conflicts arise in this paradigm between the need for industrial competitiveness and the need to protect the environment. Conflicts are resolved by performing cost-benefit analyses, weighing environmental damage against the level of technological advance and industrial profit.

The main societal problem in the environmental protection paradigm is that humans produce too much waste. The aim of the paradigm is to reduce the quantity and toxicity of waste by prevention, recycling, and waste treatment. Positive environmental progress is determined by increasing levels of energy use efficiency and more efficient use of materials [1].

2.1.2 Resource Management

In resource management, the Earth is viewed as a closed economic system, where the challenge is to "economize ecology." The environment is seen as an economic externality to be internalized (considered, included) in policy decisions and matters of economic performance. Technology is seen as the partner of environmental development, helping achieve more efficient uses of materials and energy. There is an emphasis on technology transfer from more advanced nations to less advanced nations.

Sustainable development is established by making resource users and polluters pay the true economic price of their ecological impact. Poor use of energy sources and natural resources is the main problem of human endeavors in this paradigm. Such actions threaten the ecological balance and the supply of materials industry requires for its continued survival. Proper price setting for use of environmental services provides a solution to the problem of poor resource management. Payment for environmental impact can be made in the form of tradable permits for industries to create pollution within set, sustainable, limits or taxes on pollution and the use of resources.

This view assumes that there can be a monetary value placed on environmental impact, but does not address how to arrive at those figures or account for the variability or uncertainty of monetary figures for environmental impact. In theory, the prices of materials used in manufacture would reflect the environmental impact of the use of those materials, thus providing designers with a guideline for material selection and drive up the reuse and recycling prices of materials used. The system would still be flexible enough for the manufacturers to decide how to most cost-effectively produce their products, but cleaner technology and more recyclable, green products would ultimately be the most profitable [1].

2.1.3 Eco-Development

Eco-development is the most extreme of the three views looked at in this thesis. It emphasizes that human civilization and nature exist on an equal basis. The planet is viewed a closed ecological system, rather than as an economic system. The idea is to “environmentalize the economy,” driving societal values towards environmentally healthy ends.

An eco-development viewpoint does not see the progress of economic growth as compatible with a sustainable relationship between man and nature. Sustainability in this view is seen as non-decreasing stocks of human and natural capital. These totals are independent of each other. If any doubt about ecological thresholds or the carrying capacity of the world exist for new projects or technologies, those projects or technologies must prove that they are sustainable or be dropped. Progress in this view is seen as the health of humans and the health of the ecosystem they inhabit.

Major changes in the way that humans affect the environment are essential if sustainable, closed-loop production is to be achieved. Analyses of human population, industrial capital, food production, resource consumption, and pollution show that humans are a long way from a sustainable society. Sweeping change in the behavioral, political, economic, and technological facets of our culture would be required. This is much easier said than done [2].

Eco-development requires that manufacturing be as close to closed-loop as possible. Renewable materials and energy sources are key to this paradigm. Good green designs utilize materials that are renewable. Non-renewable materials are to be used as seldom as possible, and must be recycled or reused upon product end of life. Good green design makes non-renewable materials easily separable from assemblies. Use of toxic materials in designs would be severely restricted.

Legislative policies of an eco-development system would also be much more strict. On top of tradable pollution permits or taxes on emissions, tradable permits for fixed quantities of material extraction could be issued. Use of non-renewable materials would certainly be taxed. Eco-development focuses more on meeting base human needs than taxing the environment to supply human wants [1].

2.2 World Legislation

New legislation regarding the environmental aspects of products and processes is being passed at an increasing rate. Actions taken by world governments placing greater responsibilities on manufacturers has sped the development of green design tools. The following section is a review of a selection of significant measures and initiatives taken from several countries.

2.2.1 Germany

The German Waste and Packaging law of 1991 requires retailers and manufacturers to take back and recycle all of their product packaging. This includes pallets, shipping boxes, product boxes, wrappings, and all internal protective packaging (Styrofoam cushioning, foam pads, cardboard bracers, etc.), even bottles and cans [3]. This forces producers to take responsibility for the largest segment of municipal solid waste in Germany, or 30% of the total. German manufacturers and those manufacturers selling to Germany reacted by reducing the packaging necessary for products, partly through packaging improvements and partly through product design changes. Changes in Germany effect all countries wishing to compete in the huge German market, and will push other European countries into green design at a faster rate. Ultimately, the trend may be unavoidable in the United States as well [4].

Initially, the private corporation, Duales System Deutschland, set up to handle the collection and recycling of packaging was a catastrophic failure. In its first year, it ran at a loss of \$300 million, mainly due to the fact that it took in far more materials than it expected (plastic packaging alone, initially estimated to be 105,000 tons annually was actually 409,000 tons in 1992) [5]. By revising its pricing structure, cutting costs, and benefiting from the visible decrease in packaging due to the take-back legislation, Duales now operates profitably. Waste has been reduced by almost 600,000 tons annually. That totals nearly a

4% reduction in annual municipal solid waste generated during the first two years of the program, [4].

In 1994, Germany also decreed that all televisions, computers, radios, and related electronic equipment must be taken back for recycling. It was also decreed that all new designs of effected products must be done with disassembly and material recovery in mind [6].

In an even more controversial move, automobiles have also fallen under German take-back laws. One in seven jobs in Germany is directly or indirectly related to the auto industry, either as employees of the auto makers or as suppliers to the industry. Retailers and manufacturers are required to take back, without charge, all end of life automobiles. Other regulations include 100% recycling of steels, 85% recycling of nonferrous metals, 40% of tires, 30% of glass, and 20% of plastics and elastomers [6,7].

Germany's auto recycling laws are about to become much stricter. By the year 2002, 85% by weight of junked automobiles must be recovered by the manufacturer of the vehicle. Of that total, only 5% of that reclaimed total can be from energy recovery (incineration), the other 80% reclaimed coming from recycling and reuse. By 2015, 95% by weight of junked automobiles must be recovered, with only 5% of that total attributed to energy recovery.

Before being introduced to auto shredders, vehicles must be drained of all fluids and stripped of all tires, batteries, air-conditioning systems, air bag systems, catalysts, and other hazardous materials. After shredding, all

automobile shredder residue (ASR) must be treated as hazardous, toxic waste to be placed in specialized landfills.

Manufacturers will be subjected to many new restrictions starting in the year 2002. By design, 95% of new automobile designs must be reclaimable by weight, with only five percent of that total from energy recovery. Many materials will be banned from new designs, such as hexavalent chromium, PVC, mercury, and, with the exception of batteries, lead. These new restrictions, including the mandatory take-back, apply to all automobile manufacturers selling cars in Germany, not just those manufactured in Germany [8].

Germany has also taken environmental concerns to the consumer. In 1978, it set up the "Blue Angel" eco-labeling system. It is the only well established labeling system of its kind in Europe. The label is awarded to classes of products that meet certain characteristics, such as low wastewater load for detergents. The labeling system has seen criticism due to the fact that it considers too narrow a scope of product life. Expanding the criteria for label award to cover the whole life cycle of the product is currently under study [3].

2.2.2 Japan

Japan has enacted several laws stepping towards DFD in designs, but little progress has been made. In 1991, the Law for Promotion of Utilization of Recyclable Resources was passed. This law was further strengthened by the

Waste Disposal and Public Cleansing Law of 1992. These laws requires Japanese manufacturers to label all of the items of their products that are recyclable.

Japan has a serious solid waste problem. Experts expect well over 5 million vehicles to be sent to the shredders annually [9]. While the 1991 and 1992 laws represent a major step toward mandated green design in Japan, very few manufacturers actually have done anything towards actual recycling of items. The steel content of automobiles and major appliances is recycled, but plastics, rubbers, and glass, all labeled by law, are still landfilled. Items designed specifically to be recycled very often require cumbersome and ill-planned manual disassembly. Dismantlers note that even if cars are well designed for disassembly, there still remain few reliable, profitable Japanese markets for recycled plastics. Compliance with the recycling labeling laws has become more of a marketing scheme than a useful tool for material recovery [10].

Like Germany, the Japanese government has passed an eco-labeling measure aimed at promoting environmentally friendly products to Japanese consumers. The "Eco-Mark" system was quickly embraced by Japanese industry; in just one year after the publishing of the scheme, 850 products qualified for the label in 31 different product categories. The scheme relies upon extensive marketing research showing that Japanese consumers heavily favor

environmentally sound products and, more importantly, would purchase them over less environmentally sound competitors [3].

2.2.3 Nordic Countries

The Nordic countries of Sweden, Denmark, and Norway have long been environmental legislation supporters. Taxes and deposit refunds have been useful weapons against excessive packaging for consumer products. Denmark, in particular, has banned non-refillable beverage containers, and has placed large deposit fees on returnable bottles. All new bottle designs must be government approved.

The strong ties between government and industry in these countries ease the passage and creation of environmental policy. Voluntary agreements with industry in these countries have led to many advancements. Swedish industry and the government have banned cadmium use in principle, and often phase out the use of toxic chemicals. Denmark's Clean Technology Action Plan of 1992 emphasizes decreased use of non-renewable materials in products. The Nordic countries are investigating an eco-labeling scheme (the "White Swan"), but plans are on hold pending studies for a European Community-wide system [3].

2.2.4 The Netherlands

The Netherlands has perhaps the most comprehensive national environmental policy of any country in the world. The National Environmental Policy Plan (NEPP) of 1989 and NEPP Plus of 1990, tremendously detailed and far reaching policy plans, attempt to steer the economic development of the country towards an environmentally benign road. The plans reach as far ahead as the year 2010.

The goals of the plan are nothing short of sustainable development in the Netherlands using green design, heavy investments in clean technologies (\$90 million in 1990), and product policies. Hazardous material phase-outs, such as polyvinyl chloride from packaging, cadmium, and chlorine play a large part in the policies. The plans rely mainly on voluntary industry compliance rather than command and control policies, although the government has shown no aversion to regulation if environmental goals are not met voluntarily or in a timely manner. The Netherlands has no eco-labeling scheme in place, preferring to wait for a unified European-Community standard [3].

2.2.5 The European Community

The role of the European Community in European environmental development has been that of the harmonizing influence. The difficulty in setting

policy that effects all of the Community is the differing standards and goals of the member countries; Germany's take-back laws and the comprehensive environmental policies of the Netherlands often clash with one another, for example. Harmonizing is essential to maintain that products manufactured in one country can still be sold to a country with differing or higher environmental standards. In this respect, Europe's largest market, Germany, has set a sort of de-facto standard for the other member nations.

Strict European Community standards have the possibility of unfairly penalizing the poorer member countries, while remaining below the environmental standards of countries that have already invested much time and energy in environmental concerns. More environmentally developed countries, such as Denmark and Germany, fear that European Community policies will not live up to their levels, while other nations dispute being forced to live up to policies different from their own. Recognizing that the lesser developed countries may have problems adapting to European Community standards, a two level approach is occasionally placed on tougher laws, allowing poorer nations time to adapt [3].

Also pending in the European Community is the adoption of a new standard from the International Standards Organization (ISO). Based in Geneva, ISO created the ISO 9000 standard, a group of qualifying standards for quality control and assurance. The ISO 14000 standard oversees areas of environmental interest such as environmental management, auditing,

performance evaluation, labeling, and life-cycle analysis. Like ISO 9000, ISO 14000 will require a third party audit. The ISO 14000 standard seeks to level out the vast array of differences in international environmental policies, and could become an important facet of doing business abroad in the future [11].

Eco-labeling for the entire European Community has been discussed since 1988, but development has been difficult due to the many differing goals of member nations. Label awards will be based on a life cycle analysis of candidate products, rather than meeting a few criteria, such as the German Blue Angel label. Plans for deployment have been released, but results from the program have been slow in coming. The European Community label (a daisy bordered by 12 stars) is mostly finished with development, but as of yet there is no solid date set for the beginning of the program [3].

2.2.6 The United States

United States environmental policy differs from those of European countries and Japan. Businesses are much less closely tied to the government and often take an adversarial approach to new legislation. The goals of the United States are of an environmental protection nature, while European countries tend to emulate a resource management or eco-development paradigm [3].

Hundreds of new environmental bills are introduced each year in the United States, mainly dealing with the control and reduction of toxic emissions, the regulation of hazardous wastes, and the reduction of automobile emissions. Environmental legislation, with the exception of preservation regulations for wetlands and related wildlife areas, is often based on reducing danger to humans, as opposed to holistic (all-encompassing) measures for the entire ecosystem.

National take-back laws do not exist, but many states, such as California, Massachusetts, and Rhode Island, have mandated that major appliances may not be landfilled, forcing owners to use the network of appliance recyclers set up around the country [12]. Several states have also enacted a return-deposit system for soft drink and beer containers, New York, Michigan, Maine, and Massachusetts being among the earliest states to enact these measures. Ohio has recently enacted the strictest automobile emissions standards in the country, replacing California as the program that the nation and the world looked to as the emissions reduction leader.

Product related take-back is not a reality in the United States at the present time, but many manufacturers feel that it is a distinct possibility in the near future. The initiatives taken by the United States manufacturers listed in Chapter 1 are just a few of the programs underway by the companies that would be major stake-holders in a take-back scenario. Businesses in the United States

would rather plan for these eventualities than be taken by surprise some time in the future.

Of particular interest to the present study is an air-pollution reduction program based in the heavily polluted Los Angeles area of California. The lands covered by the Regional Clean Air Incentives Market (RECLAIM) have some of the worst air quality in the world. The RECLAIM system is a unique solution that allows manufacturers to decide what is the most economically favorable way for their companies to meet the current and projected target pollution reduction goals of the air quality district. It is more flexible than current legislation in the area, and permits manufacturers to create environmental plans that are better for their businesses than the current system allows.

The program focuses on two main categories of air emissions, NO_x and SO_x gasses. Audits are performed of affected businesses, assessing their current and projected emissions. Businesses are issued pollution credits, licensing them to emit a set amount of polluting gasses per year. Companies that emit under the levels set by their audit may trade their excess credits (measured in tons of pollutant) to other companies that either choose not to or simply cannot reduce their emission levels. As the area meets and lowers the allowable amount of emissions in the district, businesses must improve the cleanliness of their operations or continue to trade with businesses that succeed in reducing their emission levels [13].

The interesting feature of this program is that it could easily be expanded to other pollutants. By extension, manufacturers could be held accountable for the environmental damage caused by their products after disposal and bring about nation-wide collection of end of life goods by the original manufacturer or a contracted third party. The eco-development idea of permits for extraction of non-renewable raw materials could also function through a similar system.

2.3 Life-Cycle Analysis

Life-cycle Analysis (LCA) is one attempt at examining the environmental impact of manufacturing. It is an exhaustive analysis of every aspect of items in a product. It encompasses all of the processes needed to extricate the raw materials for an item, the implications of its conversion to final form, its use, its disposal, and even the effects of transporting the part to each of these life stages [2].

An LCA is broken into two major sections, classification and evaluation. Classification is a mostly objective, scientific process, determining and rating all of the environmental effects of a product over its lifetime. Classification does not just look at the environmental aspects of a product left to sit in a landfill. Classification takes into account the coal burned to produce the electricity to run the injection molding machine that forms plastic items and many other aspects of its life, from cradle to grave [14,15]. Such material effects on the environment as

exhaustion of resources, greenhouse effect, acidification, smog, eutrophication, ozone depletion, human toxicity, and ecotoxicity are considered in the classification stage [16].

Evaluation is a subjective analysis of the product, based on the classification analysis. Evaluation is not scientifically based for the most part, rather it is decided by opinions from field experts and often contains political considerations. The end result is several different environmental index figures that cannot even be related to one another. This makes environmental comparison of design changes almost impossible for a design engineer who is not expert in several environmental fields [16].

The scope of an LCA is huge, and even small products can take a long time to analyze. It is a difficult, costly procedure, needing a year to complete in some cases. Life cycle analysis is not used on a grand scale due to its difficulties, although a few companies, like Volvo [17], who use a version of LCA modified by the company, use it to a limited extent. CML of the Netherlands has developed an environmental impact measurement system that is in wide use.

2.4 MET Point Overview

The MET point method of product classification is a simplified version of the CML environmental assessment method. Where the later stages of LCA require the opinions of experts, MET analysis is more scientifically based, and

less influenced by opinion. Results generated by MET analysis give product developers a single digit value for the environmental impact of a product, rather than the several different results generated by LCA classification.

The results generated by LCA are often difficult or impossible to compare to one another (the effects of greenhouse gas emission compared to the exhaustion of limited resources, for example), whereas the normalized scores of MET point analysis give an easily readable comparison of effects. Using MET analysis, environmental effects are grouped further into material use (the "M" component), energy use (the "E" component), and toxic emissions (the "T" component). Exhaustion of resources falls under the "M" factor. Greenhouse effects, acidification, smog, and eutrophication are parts of the "E" factor. Ozone depletion, human toxicity, and ecotoxicity make up the "T" factor. All three components are added together to give a single MET total for a product item. The total MET impacts of different design options can then be easily weighed against one another to determine a design of least impact.

The determination of the MET value for an item or process is accomplished using the equation:

$$\text{MET Points} = \frac{1}{n} \sum_{1}^n (E_n \cdot P \cdot 365 / T_{e_n}) \quad [18]$$

Where:

n = The number of effects quantified by CML classification (there are eight quantifiable environmental effects under CML classification, see above).

E_n = The environmental effect value for each effect, taken from CML values.

p = The population of the country in which the MET evaluation will apply.

This study uses values from the Netherlands.

365 = The number of days in a year. MET Points are normalized as the average environmental damage per day per person for the country in question.

Te_n = The target environmental effect of the country. This is the estimated annual contribution of the country to the environmental problem in question multiplied by the targeted reduction percentage for that problem for that country.

Note that this is the base conversion for a normalized total MET value taken from CML classification. Kalisvaart of TNO [16] completed a conversion table for MET calculations using population, effect, and target reduction values for the Netherlands. A copy of this proprietary information can be obtained from TNO. For MET values pertaining to materials, the weight of the material in question is multiplied by the corresponding M, E, and T points per unit weight for each life stage. For MET values pertaining to processes, the production factor for the process (surface area covered, length welded, etc.) is multiplied by the corresponding M, E, and T values for the process. Normalization of MET values to United States standards is not possible at present, as accurate standards on national contributions to the eight CML environmental concerns and target reduction values for the United States are not available.

The MET points per unit weight for several stages of the product life cycle are now available for 31 materials, covering the MET impact of extraction of raw materials, recycling, normal and special landfilling, and normal and special incineration. The M, E, and T points per unit weight are also available for 10 manufacturing processes, covering the MET impact of item production. The product use phase, which is considered in CML classification, is not currently considered in MET analysis. The MET point method was designed as a comparative tool for product designers, not as a true LCA system [16]. Chapter 3, Section 3.1.3.1 explains further simplifications to the MET tables for the purposes of the present work.

2.5 Disposal and Material Recovery Opportunities

There are three basic categories of end of life destinations for items of products, namely disposal, recycling, and reuse. Each of these destinations produces different effects both financially and environmentally.

A material recovery opportunity (MRO) is when the end of life destination of a product produces a positive (or in some instances, less negative) financial or environmental impact. For the present study, recycling and reuse are considered MRO's.

2.5.1 Disposal

Disposal of the rest fraction of a product (the items remaining when disassembly has ceased) often becomes necessary when there is no further financial or economic gain to be had from further disassembling the product. When all of the materials of worth are removed, the rest fraction only serves as a financial burden on the disassembler.

Disposal of items of a product is often the only practical solution. Many materials cannot be recycled or reused in a financially sound way. Even if a material can be recycled, there is often not a viable market for the material itself. A pile of purified chips may be fine for use in new products, but if no manufacturer wishes to use a recycled material, it is still bound for the landfill.

When items or the rest fraction of a product are disposed of in a landfill or incinerated, several losses are incurred. First, there is a financial loss. The disassembler must pay a fee for landfilling or incineration. Second, there is an environmental loss. The cumulative MET impact of material extraction and processing are lost. Further damage is done in the form of toxic emissions, material and power use in disposal of items or rest fraction in a landfill or incinerating them [18].

There are two general types of disposal methods considered in the present study- landfilling and incineration. Each of these disposal options are broken into two sub-categories- normal disposal and special disposal. Normal

disposal is used for items or rest fractions that are considered non-toxic. No further treatment of this type of disposed material is required and it may be placed in normal, less expensive landfills or burned in normal, less expensive incinerators. The scrubbers used in the smokestacks of normal incinerators are not as effective as those of special incinerators, and the methods used to line normal landfills are not as effective as those used to secure special landfills. This results in a greater impact upon the environment from normal disposal even though the materials are non-toxic.

Thus, normal disposal results in a greater negative impact to the environment and a lesser negative impact financially than special disposal. Unless an item requires special treatment due to toxicity or there remains an item in the rest fraction of an assembly that is considered toxic, all disposed items are assumed to be sent to a regular disposal destination. While it would be more environmentally sound to use a special landfill or incinerator, disassembly operations are businesses, and businesses require profits to survive.

Special disposal sites are used for items or rest fractions that are toxic. These items may be treated with compounds to help neutralize their toxic effects. More efficient scrubbers are installed in the smokestacks of special incinerators; they burn at higher temperatures to break down pollutants. Special landfills are placed in areas with large clay formations and are lined with several thick sheets of strong plastic to prevent the leeching of toxic chemicals.

2.5.2 Recycling

Recycled materials of sufficient quality and purity can be sold to manufacturers who place those materials back into the production cycle. Recycling of materials may be more productive financially and environmentally than disposal in a landfill or incinerator.

Some materials degrade, or lose some properties due to recycling. This includes most thermoplastics. Plastics that were first used in aesthetic applications may find a second life as items that are out of view of the customer. Items that had a demand for high strength or temperature resistance may find a recycled use in items that do not require such high property values. Many plastics can be recycled more than once, each time being used in a lower grade application until reaching a point where no further remolding is possible [19].

Other materials can be recycled over and over again with relatively no loss of properties. Steel can be recycled and converted into new forms as many times as it can be recovered from end of life products. Gold and other precious metals are easily reclaimed from many applications and have no problem finding suitable markets. Aluminum can be recycled many times. Recycling a given quantity of aluminum requires 90% less energy to convert to a usable form than extracting that same quantity of ore from bauxite [20].

Recycling generally results in both a gain financially and environmentally. Most materials that can be easily recycled and can find applications for their use have markets for those materials that make recycling profitable. When an item is recycled, the MET damage created by the raw material extraction for that item is reclaimed, thus reducing the negative environmental impact. While some further environmental damage may be caused by the actual recycling process, it is generally less than would be caused by disposal of the item.

2.5.3 Reuse

Reuse is the third and best option for end of life products or items of products. Disassemblers can profit financially by selling reclaimed products or items that they have disassembled from end of life products. Manufacturers that take back their own products can profit by reusing items from reclaimed products in new products, by selling reclaimed items to customers or service organizations as after-market or repair items, or by selling items reclaimed to a third party for use in unrelated products.

Environmentally, reuse is also the best option for end of life items and products. The environmental penalties associated with disposal are avoided altogether. When an item is reused, the MET points lost to extraction of raw materials and the MET points lost due to material processing are reclaimed [18]. Reuse represents the biggest possible MET improvement for items or products.

Reuse can be of great financial and environmental value. Many personal computer systems are scrapped because they are obsolete by the standards of new processors and software, not because they are defective. These whole systems can be resold to individuals, organizations, or countries that cannot afford new equipment. If total reuse is not an option due to damaged equipment, there are still valuable components that can be removed and reused from a computer system- memory, hard drive, processors, power supplies, etc.

Manufacturers that take back their own products also stand to profit from item reuse. Xerox copier items from old machines are routinely reused in new machines [7]. Should automobile take-back ever become mandatory, auto makers will certainly profit by removing useful items from returned vehicles to sell as remanufactured components.

2.6 Conclusions

Chapter 2 reviewed some of the basic philosophies of green-oriented thought, legislation, and design, as well as current and pending world legislation. The United States was shown to be in danger of a shift of legislative and trade related environmental philosophy, which would require new methods of product planning to include end of life management into early product design. Life cycle analysis was introduced, as were the reasons why it is impractical for most

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Chapter 3: Disassembly Optimization Procedure and Reporting

This chapter explains the procedures used in determining the optimal disassembly sequence for end of life products to maximize financial return while minimizing environmental impact. The methods used to generate this sequence will also give the designer a detailed description of the financial and environmental impacts of end of life products at every point of the disassembly procedure. The system is dynamic, quickly showing the effects of design or sequence changes at any stage of product development.

The system is based upon the design for environment work of Rapoza [1] and the design for disassembly work of Harjula [2] of the University of Rhode Island. Appropriate sections of their work will be referenced throughout the chapter.

3.1 Generation of the DFDE Analysis

The following section explores the methods used to generate the DFDE analysis. Before DFDE analysis it may be useful to perform a partial design for assembly analysis of the product. This will help give a clearer picture of the makeup of the product in question and will give a starting, arbitrary disassembly sequence (reverse assembly order, for example) to ease data entry into the DFDE worksheet. The assembly structure is then run through the disassembly

time generation processes of Subramani and Dewhurst [3], after which the product information is ready for entry into the DFDE spreadsheet.

3.1.1 The DFDE Workbook

The DFDE analysis workbook developed in the present work is a Microsoft Excel based application that displays both the financial and environmental effects of product disassembly. The results generated by DFDE analysis can be used to generate graphs displaying the financial and environmental effects of disassembly against time. The graphs represent dollars versus time and MET points recovered versus time.

The third group of results generated by DFDE analysis is the total "eco-dollars" generated or lost due to disassembly versus time. An eco-dollar (eco\$) is a combined measure of environmental and financial effects of disassembly, merging the financial impact of each step and the MET impact of each step normalized to a dollar figure. Eco-dollars will be discussed later in the chapter.

The DFDE Workbook runs on Microsoft Excel Version 5.0 or higher and consists of four main worksheets- three reference sheets of data plus a fourth DFDE analysis worksheet. This fourth worksheet has a built-in macro that accesses the data sheets. Copies of these worksheets can be found on Tables 3.1-3.4.

3.1.1.1 Material Codes Worksheet

The first data sheet is the Material Codes worksheet. This worksheet contains information developed by TNO of the Netherlands. The search macro built into the DFDE worksheet accesses this worksheet for all of the material specific MET point information necessary to perform the DFDE analysis. A portion of this worksheet is shown in Table 3.1: Material Codes and Properties.

The list of materials for DFDE analysis was limited at the time of this study, however, it contained many of the main materials used in manufacturing. For materials not listed, the next closest material was used. An expanded list of MET points per kilogram for different materials is under development by TNO.

The following describes the contents of the Material Codes Worksheet.

Code

Code is the material code for materials considered by the search macro. The macro returns and manipulates the data for the material from the table

Material

This column lists the materials for which MET point information is available

MET Rate Con'v

This column lists the sum of the material use, energy use, and toxic emissions MET points per kilogram for each material due to the extraction and conversion of raw materials to a processable form.

Avg Rec Content

This column lists the typical average recycled content of most materials before processing.

MET Rate Recycle

This column lists the sum of the material use, energy use, and toxic emissions MET points per kilogram for each material due to the effects of recycling that material.

Recycle \$ Rate

This column lists the price in dollars per kilogram for recycled materials. Several materials have no recycling value. This is the only column in the sheet likely to need updating, and the search macro must be rerun upon such an update.

MET Rate Landfill R

This column lists the sum of the material use, energy use, and toxic emissions MET points per kilogram for each material due to the effects of placing that material in a landfill that accepts normal waste.

MET Rate Landfill S

This column lists the sum of the material use, energy use, and toxic emissions MET points per kilogram for each material due to the effects of placing that material in a landfill that accepts special waste.

MET Rate Incin Reg

This column lists the sum of the material use, energy use, and toxic emissions MET points per kilogram for each material due to the effects of disposing of that material in an incinerator that accepts normal waste.

MET Rate Incin Spec

This column lists the sum of the material use, energy use, and toxic emissions MET points per kilogram for each material due to the effects of disposing of that material in an incinerator that accepts special waste.

3.1.1.2 Process Codes Worksheet

The second data sheet is the Process Codes sheet. The search macro built into the DFDE worksheet accesses this sheet for all of the material processing specific MET point information necessary to perform the DFDE analysis. A portion of this sheet is shown in Table 3.2: Processing Codes and Properties.

The list of processes for DFDE analysis was limited at the time of the present study, however, it contained several general processes used in manufacturing. An expanded list of MET points per process factor for different processes is still under development by TNO in the Netherlands.

Code

Code is the process code for each process. The search macro imbedded in the DFDE worksheet automatically returns and manipulates the corresponding data for that process from the Process Codes and Properties table.

Manufacturing Process

This column lists the processes for which MET point information is available

Unit

Unit refers to the unit associated with the number in the production factor column of the DFDE worksheet. Care must be taken to use the proper units associated with each process (for example, m² of material covered for powder coating, kg of material injected for injection molding, liters removed for machining, etc.).

MET Rate Con'v

This column lists the sum of the material use, energy use, and toxic emissions MET points per production factor for each process. This figure will be multiplied by the production factor to give the total MET point loss due to material processing.

3.1.1.3 Destination Codes Worksheet

The third worksheet is the Destination Codes worksheet. Unlike the first two sheets, this worksheet serves no computational purpose, but rather serves as a reference. A copy of this sheet is shown in Table 3.3: Destination Codes.

Code

Code refers to the destination code for each part or subassembly analyzed in the DFDE worksheet. The search macro imbedded in the DFDE worksheet automatically returns and manipulates the corresponding data for that process from the Process Codes and Properties table.

Destination

Destination refers to the end of life destinations described in Chapter 2, Section 2.5, Material Recovery Opportunities.

3.1.1.4 DFDE Worksheet

The DFDE worksheet contains the analysis sheets for each subassembly of the product to be analyzed. Each DFDE subassembly sheet is broken up into four main areas- the global reference section, manual entry columns, macro generated columns, and analysis columns. A separate DFDE subassembly sheet is required for each subassembly. An example of a DFDE subassembly sheet is shown in Table 3.4. The subassembly analyzed is part of an IBM PS/2

personal computer. Exploded assembly pictures of the PS/2 can be found in Appendix B.

Global Reference Section

This area of the worksheet sets several global variables. These variables may be updated or changed at any time to evaluate different design options.

Eco\$ Factor

The Eco\$ Factor is the number that is used to normalize the step MET point value to a dollar figure. Several factors determine the value of this constant. The Eco\$ Factor will be discussed in Section 3.2

Labor Rate

The Labor Rate is used to determine the hourly cost of disassembling end of life products. This factor may be adjusted to account for overhead or differing facility costs.

Regular LF Rate, \$/kg

This constant is the fee charged by a landfill that accepts normal waste. The rate entered has units of dollars per kilogram. Product items and subassemblies sent to destination "c" (Landfill, Normal, from Table 3.1: Destination Codes) and all non toxic rest fractions with a default destination of "c" will result in a negative financial impact proportional to the weight of the part, subassembly, or rest fraction.

Special LF Rate, \$/kg

This constant is the fee charged by a landfill that accepts special waste. The rate entered has units of dollars per kilogram. Product items and subassemblies sent to destination "d" (Landfill, Special, from Table 3.1: Destination Codes) and all toxic rest fractions with a default destination of "d" will result in a negative financial impact proportional to the weight of the part, subassembly, or rest fraction.

Regular Incin Rate, \$/kg

This constant is the fee charged by an incinerator that accepts normal waste. The rate entered has units of dollars per kilogram. Product items and subassemblies sent to destination "e" (Incinerate, Normal, from Table 3.1: Destination Codes) and all non toxic rest fractions with a default destination of "e" will result in a negative financial impact proportional to the weight of the part, subassembly, or rest fraction.

Special Incin Rate, \$/kg

This constant is the fee charged by an incinerator that accepts special waste. The rate entered has units of dollars per kilogram. Product items and subassemblies sent to destination "f" (Incinerate, Special, from Table 3.1: Destination Codes) and all non toxic rest fractions with a default destination of "f" will result in a negative financial impact proportional to the weight of the part, subassembly, or rest fraction.

Rest Default

Rest Default refers to the assumed final destination of the rest fraction of the main assembly at any point in the disassembly process. This section is broken into two parts, "N" and "S." The "N" refers to a rest fraction that contains no toxic items or subassemblies that may be disposed of in a normal landfill or by normal incineration. Proper entries for this category are "c" or "e," normal landfill or incinerate, with the default for an improper or no entry being "c." The "S" refers to a rest fraction that contains one or more toxic items or subassemblies that must be disposed of in a special landfill or by special incineration. Proper entries for this category are "d" or "f," special landfill or incinerate, with the default for an improper or no entry being "d."

Manual Entry Section

This worksheet area contains 12 columns. Of those 12, only columns A ("Step") and F through L ("Dis Time" through "Toxic Rest?") require any entries in order for the search macro to work. The remaining columns in this area of the worksheet, while not necessary, are useful for the interpretation and manipulation of the results of the DFDE analysis.

Column A, Step

Step refers to the entry number of the analysis. It should not be confused with the part number. The step column is a necessary part of the search macro. Each row in the subassembly sheet must have an entry in the Step column, starting beneath the title "Step" and continuing up to and including the last line of the subassembly. The search macro stops its work at the first row without an entry in the Step column.

Column B, Part Name

This column contains text describing the parts, subassemblies and operations contained in the analysis. For multi-material or multi-process items, a "-" is placed in the blank space(s) under the part name (see description for columns "Mat'l Code" and "Proc Code"). The first entry in the assembly should be placed in the same row with Step 1. The entry for that line should be the name of the product or subassembly.

Column C, Part #

This column contains the part numbers for parts, subassemblies and operations contained in the analysis. For multi-material or multi-process items, a "-" is placed in the blank space(s) under the part number (see description for columns "Mat'l Code" and "Proc Code").

The part number is broken into two. The digits before the decimal denote the subassembly that the item belongs to. The main assembly is listed as "1" and subsequent subassemblies follow in ascending order. It was found helpful

to name subassemblies in the logical order of their disassembly. However, this is not vital, as the last subassembly named may actually be the first subassembly removed depending on the results of subsequent optimization.

The remaining digits of the part number (those after the decimal) correspond to each item or operation in the subassembly. It is also helpful to name items within a subassembly in the logical order of their disassembly. Again, this is not vital. Note, the first item named in a subassembly is "1"; "0" would refer to the subassembly itself ("1.0" is the number that signifies the main assembly of the product, "1.1" denotes the first item removed or operation performed).

For removal items that are actually subassemblies to be dismantled further, a "/" is placed at the end of the part number followed by the next number available to denote a subassembly. Items in that subassembly will use the assigned extended part number as the first digits of their part number. For example:

A subassembly is removed from the main assembly. It is denoted as part number "1.14/3". This means that it is subassembly number 3 and is the fourteenth item in the main assembly. The part numbers for items in this subassembly will be numbered 3.1, 3.2, 3.3, and so on.

If an item in a subassembly is removed from the main assembly before the rest of its parent subassembly, it will still maintain a part number corresponding to the number of its parent.

Column D, Precedence

Precedence refers to the parts or subassemblies that must be removed or operations that must be performed immediately before the part or subassembly in question can be removed or the operation can be performed. An item or operation inherits the precedence items of items in its precedence list. It is not necessary to enter those items twice. For example:

The precedence items for 4.2 are (2.1, 3.2, 1.14).

The precedence items for 4.4 are (4.3, 4.2).

It is not necessary to list (2.1, 3.2, 1.14) as precedence for 4.4 as they are already entered as precedence for 4.2 in this example.

(Note: parenthesis are used around precedence groups to avoid confusion- they are not necessary on the worksheet)

This standard helps to avoid overly long precedence statements. It is necessary to ensure, however, that precedence is maintained during optimization. For multi-material or multi-process items, a "-" is placed in the blank space(s) under the precedence (see description for columns "Mat'l Code" and "Proc Code").

When entering a part number as a precedence item that has an extended part number (a subassembly), the extended part number segment is omitted.

This shows that the entire subassembly is being removed. Items of subassemblies removed as precedence items before their parent subassemblies maintain their subassembly determined part numbers.

Entries into the precedence column are placed in descending precedence order. The part number for the action immediately preceding the action for the current part number is listed first. Sequential descending part numbers in the same subassembly may be listed as follows: two items are separated with a comma; three or more items in the same subassembly in sequential order are listed as a range. For example:

If the precedence items for 4.4 are 4.3 and 4.2, precedence is entered as (4.3, 4.2).

If the precedence items for 4.4 are 4.3, 4.2, and 4.1, precedence is entered as (4.3-1).

For items that may be removed independently of one another, as in the previous example (both are available for removal at the same time), the order of listing is immaterial.

Column E, Rpt Cnt

Rpt Cnt is the repeat count, or the number of items in a disassembly step. This number is not used in the analysis calculations, but is used as a reference. For multi-material or multi-process items, a "-" is placed in the blank space(s) under the repeat count (see description for columns "Mat'l Code" and "Proc Code").

Column F, Dis Time

Dis Time is the total disassembly time for the current step. It is not the disassembly time for one part, subassembly, or operation in cases where there are more than one per step; it is the total disassembly time for the step. For multi-material or multi-process items, a zero is placed in the blank space(s) under the disassembly time (see description for columns "Mat'l Code" and "Proc Code").

Column G, Part(s) Wt.

Part(s) Wt. is the total weight for the current step. It is not the weight for one item in cases where there are more than one per step; it is the total weight for all items in the step. Operations should have entries of zero for this column. For multi-material items, the total weight is broken up for each material in the item, with the total weight for the first material placed in the first blank in the column for that item, the total weight for the second material under the total weight for the first material and so on. For items with more processes than materials, a zero is placed in the corresponding blank space(s) in the Part(s) Wt. column. Entries for subassemblies removed from a larger assembly will be the sum of the weights of all components of that subassembly. If an entry into the Prod'n Factor column is non-numerical, the search macro will generate errors in several columns. Weights entered in this analysis are in kilograms.

For entries in a parent assembly describing a daughter subassembly, the sum of the weights of all items in that subassembly is entered in this column.

Column H, Mat'l Code

Mat'l Code refers to the material code for the current step. Material codes for the materials for which MET point per kilogram totals are available are from the Material Codes worksheet of the DFDE workbook. A zero is placed in the Mat'l Code column for actions or subassemblies. An entry in the Mat'l Code column that does not appear in the Code column of the Material Codes sheet results in no value being returned by the search macro.

For items with more than one material, the first material is placed in the first blank space for this item in the Mat'l Code column. The second material is placed under the first and so on. For items with more processes than materials, a zero was placed in the corresponding blank space(s) in the Mat'l Code column.

Column I, Proc Code

Proc Code refers to the process code for the current step. Process codes for the processes for which MET point per process factor totals are from the Process Codes worksheet of the DFDE workbook. A zero is placed in the Proc Code column for actions or subassemblies. An entry in the Proc Code column that does not appear in the Code column of the Process Codes sheet will result in no value being returned by the search macro.

For items with more than one process, the first process is placed in the first blank space for this item in the Proc Code column. The second process is placed under the first and so on. For items with more materials than processes, a zero is placed in the corresponding blank space(s) in the Proc Code column.

Column J, Prod'n Factor

Prod'n Factor refers to the total production factor for all items in the current step. For multi-process items, the total production factor for the first process is placed in the first blank in the column for that item, the total production factor for the second process under the total production factor for the first process and so on. For items with more materials than processes, a zero is placed in the corresponding blank space(s) in the Prod'n Factor column.

Units for items placed in the Prod'n Factor column are from the Process Codes worksheet of the DFDE workbook. A zero is placed in the Prod'n Factor column for actions or subassemblies. If no value is placed in the Prod'n factor column, the search macro will return no value. If an entry into the Prod'n Factor column is non-numerical, the search macro will return an error.

Column K, Dest Code

This is the destination code for the step in question. A listing of destination codes can be found in Table 3.3 as well as on the Destination Codes worksheet of the DFDE workbook. Entries into the Dest Codes column not appearing on the Destination Codes table do not affect the search macro, but cause errors in several columns. The Profit (step) column will show an error for that step, and the Profit (cum.) and Eco\$ (cum.) columns will show errors for that step and all steps below it.

For multi-material or multi-process items, the Dest Code column entry is repeated for the first step of the item in each Dest Code column step that the

item takes up, with the exception or reuse items. Multi-material or multi-process reuse items will have the reuse value in dollars for the item in the first step the item occupies. The rest of the Dest Code column steps for that item will contain zeroes. Note also that the reuse value is for the total of all items reused in that step if there are more than one. Subassemblies and actions require a value of "a" in the Dest Code column. The DFDE analysis calculations assume that no entry in the Dest Code column is a reuse item.

After the search macro has been run, the destination code for subassembly entries will be changed to the immediate end of life destination for the subassembly. It is assumed that if further disassembly is required for the subassembly, that the immediate end of life destination is toxic or non-toxic disposal, depending on the makeup the subassembly components. If no further disassembly is required, the subassembly is assigned to reuse, recycling, or disposal.

Column L, Toxic Rest?

Toxic Rest? queries if the rest fraction contains toxic items after the item in the current step has been removed. Appropriate responses to this column are "y" or a blank space. If any other entry is placed in this column, the computational equations of the DFDE worksheet will assume the rest fraction is non-toxic. If there is a toxic item in the main assembly, this column should have a "y" in every step up to but not including the step where that item is removed.

Any steps not filled with a "y" up to that point will cause an error in the computation of the MET value of the rest fraction.

Macro Generated Section

This section of the DFDE worksheet contains the 8 columns that house information returned by the DFDE search macro. The information contained in these columns is in the form of number values. The rows of the spreadsheet may be rearranged for the purposes of optimization without having to re-run the macro or update these macro-generated columns. However, if the part weight, material code, process code, or production factor change for any step, the macro must be updated, or these 8 columns must be updated manually for any steps for which those values change.

After the running of the search macro, rows in parent assemblies containing entries for daughter subassemblies are edited. All subassemblies in the DFDE worksheet are listed as separate groups of items. Entries for the following 8 columns in the parent assemblies are changed to the sum of the values of these columns for the daughter subassemblies.

Column M, MET Conv

MET Conv is the total negative MET point value due to extraction and conversion of raw materials to a usable form. It is the combined M, E, and T points per kilogram taken from the Material Codes sheet for the extraction and

conversion of the material in question multiplied by the total material weight (Part(s) Wt.) for that step.

Column N, MET Prod

MET Prod is the total negative MET point value due to the production and processing of items to their final form. It is the combined M, E, and T points per production factor taken from the Process Codes sheet for the process in question multiplied by the production factor (Prod'n Factor) for that step.

Column O, MET Rec

MET Rec is the total negative MET point value due to the recycling of end of life items back to processable materials. It is the combined M, E, and T points per kilogram taken from the Material Codes sheet for the recycling of the material in question multiplied by the total material weight (Part(s) Wt.) for that step.

Column P, MET EOL NL

MET EOL NL is the total negative MET point value due to placing an end of life material in a normal waste accepting landfill. It is the combined M, E, and T points per kilogram taken from the Material Codes sheet for the normal landfilling of the material in question multiplied by the total material weight (Part(s) Wt.) for that step.

Column Q, MET EOL NI

MET EOL NI is the total negative MET point value due to placing an end of life material in a normal waste accepting incinerator. It is the combined M, E, and T points per kilogram taken from the Material Codes sheet for the normal incineration of the material in question multiplied by the total material weight (Part(s) Wt.) for that step.

Column R, MET EOL SL

MET EOL SI is the total negative MET point value due to placing an end of life material in a special waste accepting landfill. It is the combined M, E, and T points per kilogram taken from the Material Codes sheet for the normal incineration of the material in question multiplied by the total material weight (Part(s) Wt.) for that step.

Column S, MET EOL SI

MET EOL SI is the total negative MET point value due to placing an end of life material in a special waste accepting incinerator. It is the combined M, E, and T points per kilogram taken from the Material Codes sheet for the special incineration of the material in question multiplied by the total material weight (Part(s) Wt.) for that step.

Column T, Rec \$

Rec \$ is the total recycled value of the material in the step in question. The figure in this column is the recycling rate (Recycle \$ Rate) in dollars per

kilogram for the material taken from the Material Codes sheet multiplied by the total material weight (Part(s) Wt.) for the step.

Analysis Section

This section of the DFDE worksheet consists of 9 columns and contains the results of the DFDE analysis of the product in question. These columns are dynamic, and a change in the position of any of the columns due to reorganization during optimization changes the values contained in these columns. Under these circumstances it is necessary to recopy the equation lines from the first step of the analysis to the last step of the analysis to complete the reorganization steps. The first step of the analysis is never moved.

Column U, MET Rest

MET Rest is the MET point loss incurred due to disposal of the rest fraction if disassembly stopped immediately after the current disassembly step. The MET Rest value is the negative of the sum of the MET effects from material conversion and material production for all steps after the current step plus the sum of the MET effects of the end of life destination of all of the steps in the rest fraction. If the rest fraction contains any toxic materials, the end of life sum will be taken from either MET EOL SL or MET EOL SI, depending on the value for Rest Default S. If the rest fraction is non-toxic, the end of life sum will be taken from either MET EOL NL or MET EOL NI, depending on the value for Rest

Default N. Pseudo-code for the logical decisions of this column is given in Appendix A, Macro Code and Logical Operations.

Column V, Rest Disp \$

Rest Disp \$ is the monetary cost incurred due to the disposal of the rest fraction if disassembly stopped immediately after the current disassembly step. The Rest Disp \$ value is the negative of the sum of the Part(s) Wt. for all steps following the current step multiplied by the disposal rate for the end of life destination of all of the steps in the rest fraction. If the rest fraction contains any toxic materials, the disposal rate will be taken from either Special LF Rate, \$/kg or Special Incin Rate, \$/kg, depending on the value for Rest Default S. If the rest fraction is non-toxic, the disposal rate sum will be taken from either Normal LF Rate, \$/kg or Normal Incin Rate, \$/kg, depending on the value for Rest Default N. Pseudo-code for the logical decisions of this column is given in Appendix A, Macro Code and Logical Operations.

Column W, Profit (step)

Profit (step) is the monetary change for the current step. It is equal to negative Dis Time for the step multiplied by Labor Rate for the DFDE worksheet plus an effect dependent on the Dest Code for the step. Those effects are as follows:

For Reuse:	\$ value in Dest Code
For Subassembly or Action:	zero
For Recycle:	Rec \$

For Landfill, Normal:	Part(s) Wt. X Regular LF rate, \$/kg
For Landfill, Special:	Part(s) Wt. X Special LF rate, \$/kg
For Incinerate, Normal:	Part(s) Wt. X Regular Incin rate, \$/kg
For Incinerate, Special:	Part(s) Wt. X Special Incin rate, \$/kg

The Dest Code for subassemblies is changed after the first running of the search macro.

Column X, MET (step)

MET (step) is the MET point impact for the current step. The MET point change for the step is dependent on the Dest Code for the step as follows:

MET (step) =

For Reuse:	zero
For Subassembly or Action:	zero
For Recycle:	- MET Proc - MET Rec
For Landfill, Normal:	- MET Conv - MET Proc - MET EOL NL
For Landfill, Special:	- MET Conv - MET Proc - MET EOL SL
For Incinerate, Normal:	- MET Conv - MET Proc - MET EOL NI
For Incinerate, Special:	- MET Conv - MET Proc - MET EOL SI

Dest code for subassemblies is changed after the first running of the search macro.

Column Y, Time (cum.)

Time (cum.) is the sum of all Dis Time step entries from Step 1 up to and including the current step.

Column Z, Profit (cum.)

Profit (cum.) is the sum of all Profit (step) entries from Step 1 up to and including the current step plus the Rest Disp \$ for that step.

Column AA, MET (cum.)

MET (cum.) is the sum of all MET (step) entries from Step 1 up to and including the current step plus the MET Rest value for that step.

Column AB, Eco\$ (cum.)

Eco\$ (cum.) is the total Eco\$ impact of disassembly from Step 1 up to and including the current step. The step value of Eco\$ (cum.) is determined by adding Profit (cum.) and MET (cum.) for the step in question.

Column AC, Effect

Effect is the financial/environmental result of the current step. It is equal to Eco\$ (cum.) for the previous step subtracted from Eco\$ (cum.) for the current step, or:

$$\text{Effect} = \text{Eco\$}(\text{cum.})_n - \text{Eco\$}(\text{cum.})_{n-1}$$

The value of the Effect for each step will be used to optimize the order of disassembly.

3.1.2 Analysis of Effect

The effect of disassembly, is comprised of three parts: the labor expense, end of life destination, and rest fraction related portions. These categories influence the Eco\$, financial, and MET effects in different ways in different situations.

Labor expense effects are proportional to the amount of time a disassembly step takes. A disassembly operation (an unscrewing action, for example) causes no effect to the MET point total for an assembly, but will cause a negative financial effect due to the labor used to perform that operation. Every separate item or operation in the analysis will incur a negative labor expense effect. The total labor expense effect will be equal to the total disassembly time multiplied by the labor rate for the analysis. The Eco\$ labor expense effect will be equal to the financial effect.

Section 2.5 introduced end of life effects. The end of life effect of a disassembled item will generally not cause a negative total impact on the financial aspects of a product. A non-toxic item removed from a toxic rest fraction and disposed of will result in a positive financial effect. If that item had

been left in the rest fraction, it would have been charged a toxic disposal fee.

Removed from the rest fraction, it can be charged a non-toxic fee.

The rest fraction effect is also improved in this situation. The rest fraction weighs less and will be less expensive to dispose of. However, if the end of life destination of the removed item is the same as the end of life destination of the resulting rest fraction, the end of life and rest fraction improvement in the financial effects cancel out.

The end of life changes in the MET effects are the opposite of the financial effects. A non-toxic item removed from a toxic rest fraction that is then disposed of will actually cause a negative total end of life effect. The MET impact of an item in a non-toxic disposal facility is greater than that of an item in a toxic disposal facility.

This leads to another interesting situation. Special landfills and incinerators are more expensive than those used to handle non-toxic wastes. In most cases, dismantlers will use the least expensive disposal method legally available to them to keep the costs of disassembly down. For this reason, when the last toxic item in a product has been removed and the rest fraction can be considered non-toxic, the rest fraction is assumed to be routed to a non-toxic end of life destination.

Removing the last toxic item from an assembly has two immediate effects. It is assumed that rest fractions that do not contain toxic materials will be routed to an end of life disposal site that accepts only non-toxic materials. These sites

generally charge a lower dollar per unit weight fee than sites that handle toxic materials. Conversely, the environmental impact of materials placed in non-toxic disposal sites is greater than the impact of materials placed on sites that accept toxic materials.

Two important conclusions can be drawn from these observations. First, the Rest Disp \$ for the assembly will drop upon removal of the last toxic item, as the disposal cost of the rest fraction will be calculated using the lower costs associated with non-toxic waste disposal. Second, the MET Rest for the assembly will rise, as the impact of disposing of the rest fraction will be calculated using the higher MET point values associated with non-toxic waste disposal. Depending on the size and MET total of the rest fraction, removal of the last toxic item can lead to either a positive or a negative Eco\$ impact.

Recycling will cause a positive MET effect due to reclamation of material conversion MET points, and a reduction of material in the rest fraction (with the exception of the last toxic item in the assembly, see above). Financial effects of recycling may not be as obvious, as the labor cost to remove an item for recycling may be greater than the combined recycled value of that item and the decrease in the cost of disposal of the rest fraction due to rest fraction weight reduction.

Finally, reuse reclaims both material conversion and material processing MET points while at the same time reducing the amount of material in the rest fraction. Financially, the reuse value of the item is gained and the weight of the

rest fraction is reduced, causing a decrease in rest fraction disposal cost and a financial effect gain. When both the financial and environmental effects are positive, the Eco\$ effect will be positive as well.

3.1.3 The Eco-Factor

In order to optimize the disassembly order of an end of life product both financially and environmentally, it is necessary to normalize one of the units used to measure these factors (dollars and MET points) to the other. For the present study, it was decided to translate the MET point figure to a dollar amount to make the effects of disassembly easier to understand and relate to. It is much easier to think in terms of financial profit or loss than it is to think in terms of environmental damage. By normalizing the MET impact of disassembly steps to a dollar figure, a designer can get a picture of the true "environmental cost" of a product.

Relatively little has been written about assigning economic value to the environmental externalities of manufacturing and disposal. The environmental cost can be measured in several ways. The first way would be to set a cost for use and release into the environment of toxic chemicals based on the relative potency of those substances. This would require not only a determination of the damage caused by each material, it would also require relating the effects of materials and processes used. However, these requirements are loosely related

to the MET point system used in this study, but would be dollar based from the very outset. If a baseline damage cost for one material were established, its MET point value could be determined and used to create the eco-factor for normalizing MET points to a dollar figure. For example, if it were determined that the baseline environmental cost for one kilogram of unprocessed steel bar disposed of in a normal landfill was \$1, dividing the Met point total for that amount of landfilled steel bar (0.103 Met points due to conversion of raw materials, 0.125 Met points due to landfilling for a total of 0.228 MET points) would give an eco-factor of 4.39 dollars per MET point. Unfortunately, if the system used to relate the effects of different materials were not the same or close to the relative estimated damages from the MET system, the eco-factor determined from one material would be different from the eco-factor determined from another. Also, no such relative system was discovered in the literature [4].

Another approach would be to assign a direct cost to all quantifiable effects of environmental damage. For example, quantifiable effects of water pollution might be human health, human comfort, odor, animal and plant morbidity, and damage to buildings. However, even the selection and scope of effects and the methods used to measure those effects are highly subjective in nature. Estimation of a dollar damage figure would be extremely difficult. Effects would also vary from process to process, so a single figure conversion constant would not be possible [5].

A slightly more practical method of valuing environmental damage would be to approximate the cost of pending or current government regulations on pollution. This valuing system would be based on what society is willing to pay to curb or correct environmental effects. This method could certainly translate directly into a concrete dollar per effect value, such as dollars per ton of municipal solid waste or dollars per BTU of wasted energy [5,6] By extension, if regulation placed a dollar per MET point figure on emissions, raw material use, or raw material disposal, that figure would become the eco-factor used to normalize the MET point to the dollar.

Regulation such as this would drive efforts for green design and practices. For example, assume that a fee of \$4 dollars will be assessed to every MET point worth of damage released for disposal from end of life products. It would then be worth \$4 per MET point to that manufacturer to modify their designs to include more recycled or reusable items and materials and less toxic materials. It would similarly be worth \$4 per MET point to that manufacturer to remove as much material as possible for reuse or recycling from end of life products in a product take-back scenario.

A dollar rate for environmental damage has not been established in the United States, partially because the United States has not adapted a universal single digit environmental analysis system, such as the MET point method. However, a market value system for measured amounts of pollution is in place in California (the RECLAIM program described in Chapter 2). Should the United

States ever adapt a single figure environmental indicator, it is conceivable that a dollar conversion factor developed for that system would be market based.

The development of a reliable and accurate eco-factor for MET point normalization was determined to be beyond the scope of this study due to the serious lack of literature supporting the cost estimation of environmental externalities and a similar lack of support for a single figure environmental indicator outside of the Netherlands. For the case studies developed in this study, arbitrary eco-factors were utilized.

3.2 Disassembly Order Optimization

The disassembly order of an end of life product can be optimized both financially and environmentally using the results of DFDE analysis. The optimization method developed by Rapoza and Harjula was used. However in the present work the Eco\$ figure was the target for maximization. The object of optimization is to regain as much Eco\$ value as possible in the shortest time period. While the time taken for disassembly has no bearing on the MET effects of a product, time has a negative effect on the financial aspects of optimization and therefore has a negative effect on the Eco\$ total as well.

3.2.1 Product Disassembly Rules [1,2]

In order to ensure that the optimum disassembly sequence for a product can be determined, several rules were developed. In conducting an analysis of a product, subassemblies were entered onto the DFDE worksheet separate from one another, with listings and summaries for each subassembly appearing within its parent assembly. This is important, as the effect of item removal is variable, dependent on the weight and toxicity of the rest fraction.

Once a subassembly has been removed from its parent assembly, it is no longer associated with the rest fraction of that assembly, even if no further disassembly occurs on the removed subassembly. Items in the daughter subassembly are considered to be components of the rest fraction of the daughter subassembly. When the daughter subassembly is removed, the disassembly effects of its component items change as well. Consider an item removed from the daughter assembly before the daughter assembly has been removed from the parent assembly. This item is actually removed from the parent assembly in this instance, and derives its Eco\$ effect from that parent assembly.

Consider the same item removed from the daughter assembly after the daughter has been removed from the parent assembly. The Eco\$ effect of disassembly will not be the same as in the first case, due to the different

composition of the rest fraction of the daughter subassembly. It is for this reason that separate listings must be maintained for each subassembly.

From the above example, it can be seen that it is possible to remove an item by different methods or paths. The concept of a disassembly branch is derived from this conclusion. Rapoza defines a branch as "an arrangement of subassembly worksheets which represent the possible disassembly paths throughout the product [1]." A product item is originally located as far down its branch as possible at the beginning of optimization to provide the most options for disassembly sequence determination. The optimization procedure forces the item to move up its disassembly branch as necessary to discover its optimal place in the product disassembly sequence. For this study, it is assumed that:

- 1) A subassembly is the largest group of components that can be removed from a parent assembly.
- 2) A component can only be removed from within its branch.
- 3) A component must be removed from a worksheet at or above its initial worksheet location. [1,2]

These rules will assure that all possible disassembly sequence options are considered for optimization.

3.2.2 Critical Item Definition

Eco\$ optimization of an end of life product takes into account the environmental and financial aspects of all items making up that product. The removal of items with large positive or negative financial or environmental impacts determine the order of the optimized disassembly sequence. An item that causes a noticeable change in the cumulative Eco\$ value of disassembly is referred to as a critical item.

In disassembly, it is desirable to make as much of a positive Eco\$ effect due to disassembly in the shortest period of time. Therefore, during optimization critical items of high Eco\$ value that are easily and quickly removed from the product are moved up their respective disassembly branches as far as possible. Items of low or negative Eco\$ value that require a long time to remove from the assembly are pushed to the end of the disassembly order. Determining which critical item to remove first from an assembly is decided by evaluating the Eco\$ yield for each critical item at each disassembly stage.

3.2.3 Item Yield and Yield Sheets [1]

The yield of an item is defined as the sum of the Eco\$ effects of removing the precedent items for that item as well as the effect of target item removal divided by the time taken to reach the target item, or:

$$\text{Yield} = \frac{\sum (\text{Eco\$ Effects of Removal of Critical Item and Prededents})}{\sum (\text{Time Required to Remove Critical Item and Precedents})}$$

A yield sheet displays the Eco\$ yield for each critical item considered in optimization. An example yield sheet can be found in Table 3.5. Included on the yield sheet for each critical item considered in disassembly is all of the information necessary to determine the optimal product disassembly sequence order. The Part Name of the critical item is given at the top of the table. The Part #'s for the precedent items, and the Part # of the critical item are listed in disassembly order. In the next column, the disassembly time required to carry out each of these steps is listed. Finally, the Eco\$ effects of disassembly for each item is listed. The sum of the listed disassembly times is calculated. The sum of the Eco\$ effects of disassembly is also determined. Yield for the critical item is then evaluated by dividing the sum of the Eco\$ effects by the sum of the times and multiplying the result by 3600. This gives an Eco\$ yield in Eco\$/hour.

The effects of disassembly may not be constant. An item's Eco\$ effect depends on the weight and toxicity of the rest fraction that it is removed from. The value of the Eco\$ effect of each item will vary depending on which subassembly it is considered to be removed from (see Section 3.2.1). The yield for a critical item will similarly be changed if the effects of the critical item or its precedent items are changed.

3.2.3.1 Disassembly Stages

Changes in the yield of a critical item affect its desirability for removal. Another way that the yield of a critical item may change is dependent on the disassembly stage of the optimization process.

Once the yield for each critical item to be considered in the disassembly analysis has been determined, the item with the highest positive, or if no positive yields are present, lowest negative yield is removed from the assembly. The disassembly order for these items is now considered fixed. A new set of yield sheets for the remaining critical items is generated and the next disassembly stage is started.

If any of the precedence items for the removed critical item or the removed critical item itself originally appeared in the yield sheets for the remaining critical items, those entries are removed from the remaining yield sheets. While the removal of items from the previous disassembly stage may alter the Eco\$ effects of the remaining items, another important change is made when items are deleted from the remaining yield sheets. If a yield sheet loses an item, the amount of time to remove its critical item is reduced as it has fewer precedence items. Similarly, the sum of the effects of a critical item's precedence items will also be changed.

Lowering the amount of time to remove a critical item increases its yield. However, modifying the sum of the Eco\$ effects of the precedence items may

have a negative or positive result on the critical item yield. If the removed items had a net negative effect sum, the yield of the remaining critical item will increase. If the removed items had a net positive effect sum, the yield of the remaining critical item may increase or decrease, depending on the amount of time the sum of disassembly times was reduced by.

The logical model used to determine the Eco\$-optimized disassembly sequence order is shown in Figure 3.1. This decision matrix was developed by Rapoza and Harjula [1,2] at the University of Rhode Island. This optimization model, used for both the financial and environmental disassembly optimization of end of life products works equally well for the Eco\$ disassembly optimization of a product. This model, when applied to each stage of disassembly, creates a disassembly sequence that yields the highest average rate of Eco\$ return. The yield sheets for all disassembly stages of an IBM PS/2 personal computer (Case Study 1) using an eco-factor of 1 are shown in Appendix F.

3.2.5 Disassembly Example

The optimization logical model is fairly complex and requires some explanation. This section uses a hypothetical product as an example of the use of the logical model.

Consider a product with the disassembly branch structure shown in Figure 3.2a. This product consists of a main assembly with seven items. Two of

those items are subassemblies. Each subassembly consists of four items. One item in each of those subassemblies is a subassembly consisting of four parts.

Parts 4.2 and 5.4 have been determined to be the only critical items in this product. Sample yield sheets (without item effects or removal times) have been completed for each critical item and are shown at the top of Figure 3.2a.

Figure 3.2b shows the beginning for the first disassembly stage. The first item in the first yield sheet is part 1.4. This part is moved into the first available position in its DFDE subassembly sheet and its removal effect is calculated (Note: items that have been “removed” during the analysis of each yield sheet are grayed out to show they have been removed; subassemblies removed from their parent assemblies will be shown by grayed out the subassembly listing in the parent assembly and removing the arrow connecting the parent assembly with the daughter assembly). Each time an item is moved from its original location, the Eco\$ effects for all parts in the parent and daughter subassemblies must be updated to show this change.

The next item in the yield sheet to be considered is part 1.6. Figure 3.2c shows the assembly structure after part 1.6 has been moved to the first available slot in the last removed subassembly in its branch. The next item in the yield sheet to be considered is part 2.1. This part is currently situated in a DFDE subassembly sheet that has not been removed yet. Following the logic chart, part 2.1 is removed from the subassembly list for subassembly 2 and placed in

the first available slot in the last removed DFDE subassembly sheet, in this case, the main assembly (see Figure 3.2d).

The next item on the yield sheet is subassembly 2.3/4. This item is currently located in a DFDE sheet that has not been removed yet. The entry for this item is subsequently moved to the next available location in the main assembly. The results of this step are shown in Figure 3.2e. The last item in the first yield sheet is part 4.2 (see Figure 3.2f). The DFDE sheet that contains this item has been removed, meaning that the part remains in the subassembly it is listed in. It is simply moved to the first available position in its DFDE sheet.

After the critical item (part 4.2) has been removed, the disassembly effects for each item in the yield sheet are recalculated and the values are transferred to the yield sheet. According to the logic chart, as part 4.2 was the last item on its yield sheet, the next yield sheet is now considered. All DFDE subassembly sheets are returned to the structure of the previous disassembly stage (Figure 3.2g).

The first item on the second yield sheet is part 1.2. It is moved to the first available location on the main assembly DFDE sheet. This action is shown in Figure 3.2h. The second item to be considered is part 1.4. It is moved to the next available position in the main assembly (Figure 3.2i).

The next item to be removed is subassembly 1.7/3. The entry for the subassembly is moved to the next available position in the DFDE subassembly sheet for the main assembly. At this point, the subassembly is considered to be

removed from the main assembly. Items in the subassembly will be treated as rest fraction items in the removed subassembly, not the main assembly. This step is shown in Figure 3.2j.

The next item in the second yield sheet is item 3.2. The subassembly sheet it is located in has been removed, so it is moved to the first available position in its own subassembly sheet (Figure 3.2k). The last item in the second yield sheet is part 5.4 (Figure 3.2l). The subassembly it is located in has not been removed at this point, so it is moved to the last removed DFDE subassembly sheet in its branch.

This completes the second yield sheet. Removal effects for each item in the yield sheet are calculated and transferred to the yield sheet. The second yield sheet was the last yield sheet to be considered. Therefore, the critical item with the highest yield is removed from the product. In this example, it is assumed that part 5.4 has a higher yield than part 4.2. Part 5.4 is removed, ending this disassembly stage. The DFDE subassembly sheets are all updated to reflect the new disassembly order.

The second disassembly stage begins after the DFDE sheets have been updated. Items removed in the previous stage are deleted from other yield sheets (part 1.4 was a member of the yield sheet for part 5.4; it is also a member of the yield sheet for part 4.2. For the second disassembly stage, part 1.4 will not appear in the yield sheet for part 4.2). Figure 3.2.m shows the new disassembly structure for the product.

The logic chart is followed once again for the only remaining yield sheet. After the last item in the yield sheet has been removed (part 4.2), disassembly stage 2 ends. The removal effects for part 4.2's yield sheet are transferred to the yield sheet and the DFDE subassembly sheet structure is updated for each subassembly to reflect the new disassembly order. Figure 3.2n shows the final disassembly structure for the product.

3.2.5 Graphing DFDE Results

Once the Eco\$ optimization of the product is complete, the graph of the Eco\$ effects of disassembly can be made for the optimized sequence. This graph will be used to determine the cumulative effects of disassembly at all points in the disassembly sequence. Information from the DFDE subassembly sheets can be used to generate other useful curves, such as graphs of the environmental and financial effects of Eco\$ optimization. To ease the process of creating these graphs, information from the DFDE worksheet is transferred to a call sheet.

3.2.5.1 The Call Sheet

A call sheet is a collection of the product's items grouped in the desired disassembly sequence. A call sheet can reflect either the optimized or arbitrary

disassembly sequence for a product. The DFDE call sheet consists of nine columns. An example call sheet is shown in Table 3.6.

The first column contains the Part # for each item to be removed from the assembly in the proper disassembly order. The second column contains the disassembly time for each step. The third and fourth columns contain the Profit and MET effects for each step. While this information is not contained on the DFDE worksheet, it is computed the same way that the Eco\$ effect is computed (see Section 3.1.1.4, Analysis Section). The fifth column contains the Eco\$ effect for each step from the DFDE worksheet.

The remaining four columns keep a cumulative tally of the time, profit, MET, and Eco\$ effects for each step. These columns are used to create the different graphs that illustrate the effects of disassembly optimization.

3.3 Summary

Chapter 3 explained the procedures used to determine the optimal disassembly sequence for an end of life product. The database of environmental effects used to determine the Eco\$ value of disassembly items was discussed. The effects of disassembly were investigated and the eco-factor that normalizes MET point values to a dollar figure was explained. Disassembly rules and the optimization logical model was reviewed. Finally, the method to generate graphs to interpret the results of optimization were shown.

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Table 3.1: Material Codes and Properties

Code	Material	MET Rate	Avg Rec	MET Rate	Recycle	C	D	E	F
		Conv'n	Content	Recycle	\$ Rate	MET Rate Landfill R	MET Rate Landfill S	MET Rate Incin Reg	MET Rate Incin Spec
0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	sheet steel	0.088	20.000	0.043	0.120	0.125	0.010	0.050	0.072
2	steel bar/profile	0.103	20.000	0.043	0.120	0.125	0.010	0.050	0.072
3	aluminum sheet	1.030	33.000	0.060	0.700	0.010	0.001	0.105	0.072
4	aluminum bar/profile	1.030	0.000	0.060	1.050	0.010	0.001	0.105	0.072
5	copper	2.575	45.000	0.027	1.750	0.200	0.020	0.305	0.101
6	stainless steel	0.555	30.000	0.030	0.800	0.125	0.010	0.050	0.072
7	avg. ferrous metal	0.098	20.000	0.043	0.100	0.125	0.010	0.050	0.072
8	avg. non-ferrous metal	4.600	40.000	0.050	1.500	0.200	0.020	0.305	0.072
9	ABS	1.160	0.000	0.022	1.550	0.004	0.000	0.071	0.072
10	PP	0.165	0.000	0.022	0.650	0.004	0.000	0.071	0.072
11	LDPE	0.195	0.000	0.022	0.700	0.004	0.000	0.071	0.072
12	HDPE	0.160	0.000	0.022	0.700	0.004	0.000	0.071	0.072
13	PS	0.485	0.000	0.022	0.800	0.004	0.000	0.071	0.072
14	HIPS	0.415	0.000	0.022	0.800	0.004	0.000	0.071	0.072
15	EPS	0.925	0.000	0.022	0.000	0.004	0.000	0.071	0.072
16	PC	0.920	0.000	0.022	1.800	0.004	0.000	0.071	0.072
17	PVC	0.295	0.000	0.022	0.700	0.016	0.002	0.387	0.072
18	PA6	0.530	0.000	0.022	1.900	0.004	0.000	0.071	0.072
19	avg. PA	0.530	0.000	0.022	1.900	0.004	0.000	0.071	0.072
20	avg. bulk thermoplas.	0.235	0.000	0.022	0.700	0.004	0.000	0.071	0.072
21	avg. eng. thermoplas.	0.610	0.000	0.022	0.900	0.004	0.000	0.071	0.072
22	PUR	0.645	0.000	0.022	0.000	0.004	0.000	0.074	0.072
23	EPDM	0.110	0.000	0.022	0.000	0.004	0.000	0.074	0.072
24	SBR	0.620	0.000	0.022	0.000	0.004	0.000	0.074	0.072
25	glass	0.145	56.000	0.032	0.024	0.000	0.000	0.013	0.072
26	glass fiber rein.	0.145	0.000	0.032	0.000	0.000	0.000	0.013	0.072
27	wood, foreign meranti	0.143	0.000	0.000	0.024	0.000	0.000	-0.010	0.072
28	wood, local pine	0.030	0.000	0.000	0.024	0.000	0.000	-0.010	0.072
29	PCB	1.900	0.000	0.100	0.600	0.800	0.080	1.050	0.271
30	paper	0.150	45.000	0.057	0.120	0.015	0.002	0.002	0.072
31	cardboard	0.061	80.000	0.061	0.018	0.015	0.002	0.002	0.072

Table 3.2: Processing Codes and Properties

Code	Manufacturing Process	Unit	MET Rate
0	-	0	0
1	powder coating	m ²	0.045
2	electrolytic nickel plating	m ²	0.962
3	electrolytic zinc plating	m ²	0.915
4	acrylic water based paint	m ²	0.01
5	injection mold thermoplastics	kg	0.044
6	extrusion thermoplastic	kg	0.018
7	extrusion aluminum	kg	0.035
8	bending	1000m*mm ² folded	0.044
9	MIG weld 2mm thick	m	0.065
10	machining/drilling	l removed	0.035

Table 3.3: Destination Codes

Code	Destination
\$\$	Reuse
A	Subassembly or Action, no Met impact
B	Recycle
C	Landfill, Normal
D	Landfill, Special
E	Incinerate, Normal
F	Incinerate, Special

Eco \$ Factor:	1.00	Global Values		
Labor Rate:	30.00			
Regular LF rate, \$/kg	0.04			
Special LF Rate, \$/kg	0.07			
Regular incin Rate, \$/kg	0.05			
Special incin Rate, \$/kg	0.09			
		Rest	c	N
		Default:	f	S

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	IBM PS2	1.0	-	1.00	0.0	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Screw Unfasten	1.1	-	2.00	20.2	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Cover ssy	1.2/2	1.1	1.00	4.2	1.231	0	0	0	c	y	0.312	0.030	0.048	0.124	0.067	0.010	0.089	0.558
4	Cover Thumb Scrs	1.3	1.1	2.00	6.4	0.013	2	10	1.6E-7	b	y	0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.002
5	-	-	-	-	0.0	0.003	16	5	0.004	b	y	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
6	Slot Covers	1.4	1.2	3.00	21.9	0.013	1	10	4.9E-6	b	y	0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.002
7	Drive Bracket ssy	1.6/3	1.2	1.00	12.0	3.328	0	0	0	d	y	3.950	0.081	0.183	0.622	1.007	0.062	0.387	3.960
8	Power Sup Screws	1.7	1.2	3.00	21.3	0.012	2	10	2E-04	b	y	0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.001
9	Power Supply	1.8	1.7	1.00	4.2	0.800	1	3	0.232	2.00	y	0.070	0.212	0.034	0.100	0.040	0.008	0.058	0.096
10	-	-	-	-	0.0	0.333	9	9	0.127	0.00	y	0.387	0.008	0.007	0.001	0.024	0.000	0.024	0.517
11	-	-	-	-	0.0	0.333	29	5	0.356	0.00	y	0.633	0.016	0.033	0.267	0.350	0.027	0.090	0.200
12	Mthr Brd Bck Scrs	1.9	-	3.00	21.3	0.005	2	10	5E-05	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
13	Mthr Brd Btm Scrs	1.10	1.6	3.00	21.3	0.005	2	10	5E-05	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
14	Mother Board	1.11	(1.10-8)	1.00	3.9	0.978	29	9	0.102	b		1.858	0.007	0.098	0.782	1.027	0.078	0.265	0.587
15	Slot Cover Holder	1.12	1.11	1.00	5.6	0.030	1	10	1.6E-6	b		0.003	0.000	0.001	0.004	0.002	0.000	0.002	0.004
16	Plastic Brcket	1.13	1.2	1.00	3.2	0.002	9	5	0.003	b		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003
17	Nut	1.14	1.2	1.00	13.6	0.002	2	10	1.6E-7	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	Star Washer	1.15	1.14	1.00	3.8	0.002	1	10	1.6E-8	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	Locking Bracket	1.16	1.15	1.00	3.8	0.020	1	10	1.6E-6	b		0.002	0.000	0.001	0.002	0.001	0.000	0.001	0.002
20	Lock Retainer Clip	1.17	1.2	1.00	7.8	0.002	1	10	1.6E-6	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	Lock	1.18	1.17	1.00	3.8	0.034	2	10	1.6E-6	0.50		0.004	0.000	0.001	0.004	0.002	0.000	0.002	0.004
22	Lock Position Ring	1.19	1.18	1.00	3.8	0.001	16	5	0.002	b		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
23	Bottom Sticker	1.20	-	1.00	5.0	0.001	16	5	0.001	c		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
24	Back Stickers	1.21	-	3.00	15.0	0.003	16	5	0.003	c		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
25	Steel Wool Inserts	1.22	1.11	6.00	34.8	0.005	1	7	0.006	c		0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
26	Threaded Inserts	1.23	1.11	4.00	41.4	0.020	2	10	6.5E-6	c		0.002	0.000	0.001	0.002	0.001	0.000	0.001	0.002
27	Rubber Feet	1.24	-	4.00	20.0	0.016	23	5	0.016	c		0.002	0.001	0.000	0.000	0.001	0.000	0.001	0.000
28	Base	1.25	1.24-1	1.00	3.8	0.782	16	5	0.844	b		0.720	0.037	0.017	0.003	0.056	0.000	0.056	1.408
29	-	-	-	-	0.0	0.000	0	1	0.361	b		0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Manual Entry Section												Macro Generated Section							

Table 3.4a Example DFDE Sheet
100

Harness		
Part #	Dis Time	Effect
1.10	41.4	-0.34287
1.11/3	10.1	-0.06570
1.14/10	29.5	-0.22308
1.17	16.7	135.82970
1.19	20.2	36.16672
1.20	12.8	-0.07982
1.22	9.6	-0.05763
1.23	11.2	-0.09333
1.32	27.0	-0.22287
1.33	5.4	204.42485
1.34	6.4	0.08091
1.35	49.2	-0.40680
1.36	4.8	36.23102
1.43	3.9	-0.00471
1.44	3.8	-0.03042
1.45	3.9	-0.00471
1.46	3.8	-0.03042
1.47	96.3	-0.80250
1.51	6.7	157.84816
Sum	362.7	568.21651
	Yield	5639.86613

Table 3.5 Example Yield Sheet

CALL SHEET, ECOFACTOR:4

Arbitrary Disassembly Order

Part #	Dis Time	Profit Effect	MET Effect	Eco\$ Effect	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)
1.0	0.0	-0.71771	-9.34670	-38.10449	0.0	-0.71771	-9.34670	-38.10449
1.1	20.2	-0.16833	0.00000	-0.16833	20.2	-0.88604	-9.34670	-38.27283
1.2/2	4.2	0.02656	-0.03567	-0.11613	24.4	-0.85949	-9.38237	-38.38896
1.3	6.4	-0.04549	0.00435	-0.02811	30.8	-0.90498	-9.37802	-38.41706
1.4	21.9	-0.17970	0.00156	-0.17346	52.7	-1.08468	-9.37646	-38.59052
1.6/3	12.0	-0.03343	0.32500	1.26657	64.7	-1.11811	-9.05146	-37.32395
1.7	21.3	-0.17498	0.00158	-0.16864	86.0	-1.29309	-9.04987	-37.49259
1.8	4.2	2.09700	1.49851	8.09105	90.2	0.80391	-7.55136	-29.40154
1.9	21.3	-0.17638	0.00070	-0.17356	111.5	0.62753	-7.55066	-29.57511
1.10	21.3	-0.17638	0.00070	-0.17356	132.8	0.45115	-7.54995	-29.74867
1.11	3.9	0.68810	2.07363	8.98260	136.7	1.13925	-5.47633	-20.76607
1.12	5.6	-0.04183	0.00514	-0.02128	142.3	1.09741	-5.47119	-20.78735
1.13	3.2	-0.02384	0.00203	-0.01572	145.5	1.07357	-5.46916	-20.80307
1.14	13.6	-0.11305	0.00033	-0.11173	159.1	0.96053	-5.46883	-20.91480
1.15	3.8	-0.03138	0.00030	-0.03017	162.9	0.92914	-5.46853	-20.94497
1.16	3.8	-0.02854	0.00332	-0.01524	166.7	0.90061	-5.46520	-20.96021
1.17	7.8	-0.06472	0.00030	-0.06351	174.5	0.83589	-5.46490	-21.02372
1.18	3.8	0.46970	0.00780	0.50091	178.3	1.30559	-5.45710	-20.52281
1.19	3.8	-0.03003	0.00080	-0.02682	182.1	1.27556	-5.45630	-20.54963
1.20	5.0	-0.04167	0.00000	-0.04167	187.1	1.23389	-5.45630	-20.59130
1.21	15.0	-0.12500	0.00000	-0.12500	202.1	1.10889	-5.45630	-20.71630
1.22	34.8	-0.29000	0.00000	-0.29000	236.9	0.81889	-5.45630	-21.00630
1.23	41.4	-0.34500	0.00000	-0.34500	278.3	0.47389	-5.45630	-21.35130
1.24	20.0	-0.16667	0.00000	-0.16667	298.3	0.30723	-5.45630	-21.51796
1.25	3.8	1.40762	0.70556	4.22988	302.1	1.71485	-4.75073	-17.28808
2.1	10.0	-0.08333	0.00000	-0.08333	312.1	1.63152	-4.75073	-17.37142
2.2	13.4	-0.01026	0.04971	0.18858	325.5	1.62125	-4.70102	-17.18284
2.3	8.8	0.27177	0.16918	0.94847	334.3	1.89302	-4.53185	-16.23437
2.4	25.0	-0.20691	0.00164	-0.20033	359.3	1.68611	-4.53020	-16.43470
2.5	3.8	0.12478	0.16622	0.78967	363.1	1.81089	-4.36398	-15.64503
3.1	8.8	0.93619	0.06297	1.18807	371.9	2.74708	-4.30101	-14.45696
3.2	8.8	5.01467	1.26524	10.07561	380.7	7.76174	-3.03577	-4.38135
3.3	3.2	-0.02648	0.00012	-0.02601	383.9	7.73526	-3.03566	-4.40736
3.4	3.8	0.01157	0.12978	0.53070	387.7	7.74684	-2.90587	-3.87666
3.5	8.8	15.03227	1.52301	21.12430	396.5	22.77910	-1.38287	17.24764
3.6	3.2	0.12996	0.47012	2.01043	399.7	22.90907	-0.91275	19.25807
3.7	36.4	-0.26217	0.02112	-0.17768	436.1	22.64689	-0.89162	19.08040
3.8	22.4	-0.14551	0.02112	-0.06101	458.5	22.50139	-0.87050	19.01939
3.9/4	3.2	-0.02277	0.01682	0.04451	461.7	22.47861	-0.85368	19.06390
3.10	3.8	-0.00996	0.00054	-0.00779	465.5	22.46865	-0.85313	19.05611
4.1	5.0	-0.04162	0.00006	-0.04138	470.5	22.42703	-0.85307	19.01473
4.2	13.4	-0.10495	0.00345	-0.09115	483.9	22.32208	-0.84963	18.92358
4.3	6.4	-0.04157	0.00604	-0.01743	490.3	22.28051	-0.84359	18.90615
4.4	5.3	-0.04392	-0.00259	-0.05427	495.6	22.23659	-0.84618	18.85188
4.5	19.2	-0.15832	0.00106	-0.15410	514.8	22.07827	-0.84512	18.69779
4.6	3.8	0.97977	0.24198	1.94770	518.6	23.05804	-0.60314	20.64549
4.7	3.8	0.05149	0.04268	0.22221	522.4	23.10954	-0.56046	20.86770

Table 3.6 Example Call Sheet

Figure 3.1 Optimization Logical Model

Figure 3.2a Original Disassembly Structure

Figure 3.2b Structure After Removal of Part 1.4

Figure 3.2c Structure After Removal of Part 1.6

Figure 3.2d Structure After Removal of Part 2.1

Figure 3.2e Structure After Removal of Subassembly 2.3/4

Figure 3.2f Structure After Removal of Part 4.2

Figure 3.2g Original Disassembly Structure Reset for Second Yield Sheet

Figure 3.2h Structure After Removal of Part 1.2

Figure 3.2i Structure After Removal of Part 1.4

Figure 3.2j Structure After Removal of Subassembly 1.7/3

Figure 3.2k Structure After Removal of Part 3.2

Figure 3.2I Structure After Removal of Part 5.4

Figure 3.2m Structure at Beginning of Disassembly Stage 2

Yield Sheet 1
1.6
2.1
2.3/4
4.2

Yield Sheet 2
1.2
1.4
1.7/3
3.2
5.4

Main Assmebly, 1.0
1.2
1.4
1.7/3
1.6
2.1
2.3/4
1.1
1.3
1.5/2

▼

Subassembly 2.0
2.2
2.4

Subassembly 3.0
3.2
5.4
3.1
3.3
3.4/5

Subassembly 4.0
4.2
4.1
4.3
4.4

◀

Subassembly 5.0
5.1
5.2
5.3

Figure 3.2n Structure at End of Disassembly Stage 2

Chapter 4: Case Study Analysis

This chapter discusses the findings of the two case studies developed in the present work. The two consumer products evaluated were an IBM PS/2 personal computer and a General Motors C/K Truck dashboard. The effects of using different eco-factors on optimization will be explored. The differences between products with high end of life financial values and low end of life financial values will also be discussed. Finally, logical points for stopping disassembly will be reviewed.

4.1 Case Study 1: IBM PS/2 Personal Computer

The issue of dealing with end of life computer equipment is of growing concern, as was discussed in Chapter 2. This section explores the end of life impact of an IBM PS/2 personal computer (hereafter referred to as the PS/2).

The PS/2 is a computing product that is now obsolete and is a good example of machines that are now clogging the waste disposal systems of the nation. The PS/2 was a very well designed model, and is an exceptional example of design for assembly principles. This model of computer is very easy to assemble, and is similarly easy to disassemble. The body of the computer weighed 8 kilograms and measured 43 cm long by 36 cm wide by 14 cm tall. The assembly consisted of 88 parts in four analyzed assemblies. Several items

normally considered subassemblies but of little to no value if disassembled (the hard drive and the power supply, for example) were not taken apart and were subsequently treated as complete items. An exploded view of the PS/2 is shown in Appendix B.

A partial design for assembly analysis was carried out on the PS/2 to establish item characteristics and a product assembly structure. This assembly structure was then used to generate an arbitrary disassembly sequence using the reverse of the order of assembly. This information was then transferred to the DFDE worksheet.

The total time to disassemble the entire computer was estimated to be 522.4 seconds. This includes several operations that would not be included in the careful disassembly of the product, such as snapping out the metal inserts molded into the base. Table 4.1 lists the monetary reuse values assigned to the major components of the computer.

Once entered into the DFDE worksheet, the disassembly sequence of the PS/2 was optimized for the highest Eco\$ total in the least time. This financial / environmental optimization was carried out for eco-factors of 1 and 4 (i.e. 1 MET point = \$1 and 1 MET point = \$4). Copies of the DFDE subassembly sheets for the arbitrary disassembly sequence and the optimized sequences for the eco-factor 1 optimization are shown in Appendix D. Table 4.3 shows the call sheet used to generate the eco-factor 1 arbitrary sequence graph, and Table 4.4 shows the call sheet for the eco-factor 1 optimized disassembly sequence.

Using an eco-factor of 1, the maximum Eco\$ value obtained from disassembly was 22.79 Eco\$ at 431.2 seconds. This maximum value is achieved 91 seconds faster than the maximum value for the arbitrary sequence, or 21% faster. Figure 4.1 shows the graph of the Eco\$ effects of disassembly using the optimized disassembly sequence. It also shows the locations of several key disassembly steps and the names of the critical items removed at those steps. Figure 4.2 shows the graph of the financial, environmental, and Eco\$ effects of disassembly using the arbitrary disassembly sequence. Figure 4.3 shows the graph of the financial, environmental, and Eco\$ effects of disassembly using the optimized disassembly sequence. Figure 4.4 shows the graph of the Eco\$ effects of disassembly using the arbitrary disassembly sequence compared to the optimized disassembly sequence.

From Figure 4.4, stopping disassembly at the point of maximum Eco\$ gain yields a return rate of 190 Eco\$/hour. However, it can be seen that much greater potential lies in stopping disassembly for this product at or closer to the point of greatest rate of return. By stopping disassembly at 42 seconds, an Eco\$ gain of 12.59 is realized. In less than 1/10 of the time necessary to achieve the highest Eco\$ gain, more than 50% of the highest obtainable Eco\$ value can be removed from the product. Instead of only gaining 190 Eco\$/hour, it is possible to gain 1080 Eco\$/hr by stopping at the point of highest return rate.

For an eco-factor of 4, a maximum return of 20.27 Eco\$ is achieved at 460 seconds. This is 2.52 Eco\$ less than can be removed from the eco-factor 1 disassembly scenario. However, it is difficult to draw meaningful comparisons between the two sequences in terms of maximum Eco\$ return. The Eco\$ is a relative figure, determined by the eco-factor.

Table 4.5 shows the call sheet for the eco-factor 4 optimized disassembly sequence. Figure 4.5 shows the graph of the Eco\$ effects of disassembly using the optimized disassembly sequence. The graph also displays several important points in the disassembly sequence and the critical items removed from the assembly at those points. Figure 4.6 shows the combined graph of the financial, environmental, and Eco\$ effects of disassembly using the Eco\$ optimized disassembly sequence. Finally, Figure 4.7 shows a comparison graph of the Eco\$ effects of disassembly using the arbitrary and optimized disassembly sequences

An important observation can be made in this case. The PS/2 is a product with high portions of recyclable or reusable materials where the dollar value that can be reclaimed from the assembly greatly outweighs the cost of total disassembly. The maximum Eco\$ reclaimed for the two different eco-factors will be similar, as most of the MET value that can be regained from the assembly has been reclaimed at the maximum Eco\$ point. The differences in the maximum Eco\$ reclaimed from the two sequences is largely due to the higher penalty due to the eco-factor, not differences in disassembly time.

An eco-factor of 4 slowed the return rate. A maximum Eco\$ return rate of 334 Eco\$/hour was achieved at 138 seconds. Stopping disassembly at this point brings a total gain of 12.80 Eco\$. The Eco\$ amount reclaimed from the assembly at the point of highest return rate is nearly the same as the amount reclaimed for the optimized sequence for an eco-factor of 1. However, the higher eco-factor has increased the amount of time to get to the highest return rate by a factor of three.

By increasing the eco-factor used to weigh the effects of disassembly, more emphasis is placed upon the environmental aspects of the end of life product. At the maximum return rate point for the eco-factor 1 sequence, the MET point total for disposal of the rest fraction is -6.59 points. This represents only a 2.76 MET point improvement due to disassembly from the 9.35 MET point loss that would have resulted from disposal with no disassembly. However, by increasing the eco-factor to 4, the MET point total for disposal of the rest fraction at the point of maximum Eco\$ rate return is -2.41 MET points. This represents a 6.94 MET point improvement due to disassembly.

4.2 Case Study 2: 1995 General Motors C/K Truck Dashboard

Millions of vehicles are disposed of annually around the world. It is predicted that laws for the end of life treatment of automobiles will become stricter over the next several years. More reuse and greater recycling of end of

life automobile components will certainly be a part of any future legislation. The second case study carried out for the present work, the DFDE analysis of a 1995 model year General Motors C/K Truck dashboard (hereafter referred to as C/K dash), addresses this issue. An exploded view of several major components of the C/K dash can be found in Appendix C.

As mentioned in Chapter 1, plastics make up a major portion of the residue left after automobile shredding. In the present example, 14.2 kg out of the 20.9 kg that make up the dashboard are plastics.

The dimensions of the dashboard are 1.63 m x 0.51 m x 0.46 m. A dash such as the one used for this study would be purchased by a dismantler as part of a vehicle whose life has been brought to an end prematurely. These vehicles have usually been through a major accident and have been declared "totaled" by the insurer. As will be demonstrated, a dashboard unit in good condition can be worth several hundred dollars to a dismantler, and planning for proper material recovery is worth investigating. Values for reusable dashboard components were obtained for the present study from an automobile dismantler [1]. Table 4.2 lists some of the dashboard items with high reuse values.

It was estimated that the entire dash would take 1126 seconds (18 minutes, 46 seconds) to dismantle using an arbitrary disassembly sequence. The assembly consisted of over 145 parts and subassemblies and many more operations. Due to the large size of the analysis, the operations needed to remove an item were, for the most part, consolidated into the entry for that item.

If the item could be removed in more than one way or the removal of other items would change the time needed to remove the item in question, the operation was listed separately.

Several items normally considered subassemblies but of little to no value if disassembled (the instrument cluster and the Temperature/HVAC controller, for example) were not taken apart and were subsequently treated as parts. In the optimized sequence, clumping of items was used to a limited extent to decrease disassembly time. For example, most of the parts of the adjustable air vents are composed of the same material. When all items not of this same material were removed from the vent, disassembly was stopped on the vent. The remaining parts were recycled as a unit. However, clumping only decreased the total disassembly time by 14 seconds.

The call sheet for the Eco\$ optimized disassembly sequence is shown in Table 4.6. An eco-factor of 3 was used to optimize the dashboard for disassembly. Due to the high dollar value of the reusable parts of the assembly, the environmental aspects of the assembly played very little part in determining the disassembly sequence. Figure 4.8 gives a clearer picture of how the financial aspects of the assembly affected the sequence. The Eco\$ line mimics the financial line very closely. Figure 4.9 shows a graph of the Eco\$ effects of disassembly using the Eco\$ optimized disassembly sequence. The graph also labels several major points in the disassembly sequence and lists the critical items removed at those points. Finally, Figure 4.10 shows a comparison graph

of the Eco\$ effects of disassembly for the optimized and arbitrary disassembly sequences.

The maximum Eco\$ value obtained for the assembly was 912.87 Eco\$ at 952 seconds into the disassembly sequence. The financial line for the Eco\$ optimization reaches a maximum at \$915.53 at 816 seconds into the disassembly sequence. However, it should be noted that the two curves essentially level out after the removal of the base molding, (See Figure 4.8) and that at the point of the maximum financial return, the Eco\$ line is at a value of 912.27 Eco\$, a figure very near the financial value. Copies of the DFDE subassembly worksheets for the C/K dash can be found in Appendix E.

In most respects, the Eco\$ line is a mirror of the financial line. This is due partly to the scale of the graph. However, this case demonstrates the highly relative nature of the Eco\$. If a product has great reuse or recycling value and little environmental impact, the graph of the Eco\$ effects of disassembly will more closely resemble the graph of the financial effects of disassembly. It can also be assumed that if a product has a low end of life financial value and an extremely high environmental impact or if a high eco-factor is used to analyze the product, the graph of the Eco\$ effects of disassembly will more closely resemble a scaled graph of the environmental effects of disassembly.

The maximum rate of return is achieved at 89 seconds into the disassembly sequence, at a rate of 14776.82 Eco\$/hour. This is a much higher rate of return than the rate at the point of the removal of the base molding, which

is 5128.56 Eco\$/hour. However, several factors weigh against stopping disassembly at the point of highest return rate. There is an extremely high dollar value that resides in the rest fraction at the point of highest return (\$517.48 can still theoretically be extracted from the rest fraction). There is also a high potential for significant environmental improvement in continuing the disassembly process (almost 14 MET points worth of negative environmental impact can be avoided by continuing disassembly). Lastly, the supply of C/K Truck dashboards that see early retirement is assumed to be not very large. It is reasonable to assume that disassembly would continue at least until the base molding of the assembly was removed. An extra 548 seconds would be dedicated to the disassembly of the rest fraction for a financial gain of \$516.94 and an environmental recovery effect of 8.68 MET points.

Another Eco\$ analysis of the C/K dash was carried out assuming that none of the parts were reusable. This scenario assumes that the assembly is being reclaimed at its natural end of life or because the reusable parts of the assembly have gone through a trauma that prohibits reuse (side impact collision, for example). This scenario does not assume that any trauma has changed the time to disassemble the dash, nor does it assume that age has effected the recycling value of the component materials.

An eco-factor of 3 was used again to analyze the dash. Figure 4.11 shows the graph of the Eco\$ effects of disassembly and the names of the critical items removed at the majors steps in the disassembly sequence. This graph

reveals that disassembly of the dash will never be "profitable" from an Eco\$ viewpoint. However, Figure 4.12 shows that financial profit can be made from the disassembly of the dash; a maximum of \$7.11 can be made from disassembling the dash for 1031 seconds. It should be noted that this is in the flattened out region of the graph after the last major critical item has been removed. \$6.24 can be reclaimed from the assembly after 722 seconds. As much as 13.50 MET points can be recovered by disassembly of the dash. This represents a significant environmental improvement.

While the potential for profit and environmental improvement exist, it is not likely that the amounts of the benefits will be high enough to entice a disassembler to spend the time necessary to perform these tasks. Unless a financial penalty relative to the size of the environmental impact of disposal were imposed upon end of life products, this assembly would most likely end up as shredder residue.

4.3 Stopping Points for Disassembly

Several deciding factors in determining when to stop disassembly have already been explored in this chapter. This section reviews these points in more detail.

The first deciding factor is highest return. Since Eco\$ optimization accounts for the financial and environmental aspects of disassembly, the point of

highest return should yield the best mix of financial and environmental gains. The point of highest Eco\$ return represents close to if not exactly the point of highest financial return and is usually quite close to the point of highest environmental return (see Figures 4.3, 4.6, 4.8, and 4.12).

The second deciding factor is highest rate of return. This point in the disassembly sequence represents the greatest amount of positive impact in the least amount of time. Very often, this point occurs early in the disassembly sequence. Raising the eco-factor applied to the MET effects of disassembly tends to increase the amount of time taken to get to the point of highest return rate. This in turn tends to increase the amount of positive environmental recovery before reaching the point of highest return rate.

The volume of products to disassemble may play a large part in determining when to stop disassembly. If the volume is high enough, a simple time constraint may determine when disassembly must stop. If this is the case, disassembly return rate becomes more important.

Time constraints may play a role in whether or not disassembly begins at all. If a company determines that the amount of time it takes to realize a profit from disassembly is not worth the effort or attention, disassembly may be neglected altogether.

If volume is low or the reclaimable value of the product is high, the disassembly stopping point will be closer to the point of maximum return. In the case of the C/K dashboard, where items could be reused it is difficult to justify

not spending the additional 9 minutes of disassembly time to realize an additional profit of \$517.

Finally, a company may set environmental or profit goals for disassembly projects. A standard could be adopted by the company not to stop disassembly until at least some certain amount of reclaimable value has been attained. For example, Company X may set a rule for itself that 50% of the possible MET points that can be reclaimed from a product must be reclaimed before disassembly can be stopped. This type of deciding factor could also be mandated by law, should product reclamation ever become a legal requirement.

4.4 Summary

Chapter 4 reviewed the case studies carried out to support the present work. The results of the case studies show that optimizing the order of disassembly for Eco\$ return yields significant improvements both financially and environmentally over an arbitrary disassembly sequence. Eco\$ optimization offers an alternative to strict environmental or financial optimization methods.

Reactions of the Eco\$ effect graph to different situations were investigated. The results of using two different eco-factors to evaluate the same product were explored. Also investigated was the effect of high and low end of life financial values for the same product. Finally, deciding factors for stopping disassembly were discussed.

Literature Cited

- [1] Pricing Structure, Schram Auto and Truck Parts, Waterford, Michigan, July, 1996.

CALL SHEET, ECOFACTOR:1

Arbitrary Disassembly Order

Part #	Dis Time	Profit Effect	MET Effect	Eco\$ Effect	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)
1.0	0	-0.71771	-9.34670	-10.06441	0.0	-0.71771	-9.34670	-10.06441
1.1	20.2	-0.16833	0.00000	-0.16833	20.2	-0.88604	-9.34670	-10.23274
1.2/2	4.2	0.02656	-0.03567	-0.00912	24.4	-0.85949	-9.38237	-10.24186
1.3	6.4	-0.04549	0.00435	-0.04115	30.8	-0.90498	-9.37802	-10.28300
1.4	21.9	-0.17970	0.00156	-0.17814	52.7	-1.08468	-9.37646	-10.46114
1.6/3	12	-0.03343	0.32500	0.29157	64.7	-1.11811	-9.05146	-10.16957
1.7	21.3	-0.17498	0.00158	-0.17340	86.0	-1.29309	-9.04987	-10.34297
1.8	4.2	2.09700	1.49851	3.59551	90.2	0.80391	-7.55136	-6.74746
1.9	21.3	-0.17638	0.00070	-0.17568	111.5	0.62753	-7.55066	-6.92313
1.10	21.3	-0.17638	0.00070	-0.17568	132.8	0.45115	-7.54995	-7.09881
1.11	3.9	0.68810	2.07363	2.76173	136.7	1.13925	-5.47633	-4.33708
1.12	5.6	-0.04183	0.00514	-0.03669	142.3	1.09741	-5.47119	-4.37378
1.13	3.2	-0.02384	0.00203	-0.02181	145.5	1.07357	-5.46916	-4.39559
1.14	13.6	-0.11305	0.00033	-0.11272	159.1	0.96053	-5.46883	-4.50831
1.15	3.8	-0.03138	0.00030	-0.03108	162.9	0.92914	-5.46853	-4.53939
1.16	3.8	-0.02854	0.00332	-0.02521	166.7	0.90061	-5.46520	-4.56460
1.17	7.8	-0.06472	0.00030	-0.06441	174.5	0.83589	-5.46490	-4.62901
1.18	3.8	0.46970	0.00780	0.47750	178.3	1.30559	-5.45710	-4.15151
1.19	3.8	-0.03003	0.00080	-0.02923	182.1	1.27556	-5.45630	-4.18074
1.20	5	-0.04167	0.00000	-0.04167	187.1	1.23389	-5.45630	-4.22240
1.21	15	-0.12500	0.00000	-0.12500	202.1	1.10889	-5.45630	-4.34740
1.22	34.8	-0.29000	0.00000	-0.29000	236.9	0.81889	-5.45630	-4.63740
1.23	41.4	-0.34500	0.00000	-0.34500	278.3	0.47389	-5.45630	-4.98240
1.24	20	-0.16667	0.00000	-0.16667	298.3	0.30723	-5.45630	-5.14907
1.25	3.8	1.40762	0.70556	2.11319	302.1	1.71485	-4.75073	-3.03588
2.1	10	-0.08333	0.00000	-0.08333	312.1	1.63152	-4.75073	-3.11922
2.2	13.4	-0.01026	0.04971	0.03945	325.5	1.62125	-4.70102	-3.07977
2.3	8.8	0.54354	0.33835	0.44094	334.3	2.16479	-4.36267	-2.63882
2.4	25	-0.20691	0.00164	-0.20527	359.3	1.95788	-4.36103	-2.84409
2.5	3.8	0.12478	0.16622	0.29100	363.1	2.08266	-4.19481	-2.55309
3.1	8.8	0.93619	0.06297	0.99916	371.9	3.01885	-4.13184	-1.55393
3.2	8.8	5.01467	1.26524	6.27990	380.7	8.03351	-2.86660	4.72597
3.3	3.2	-0.02648	0.00012	-0.02636	383.9	8.00703	-2.86648	4.69961
3.4	3.8	0.01157	0.12978	0.14136	387.7	8.01861	-2.73670	4.84096
3.5	8.8	15.03227	1.52301	16.55528	396.5	23.05087	-1.21369	21.39624
3.6	3.2	0.12996	0.47012	0.60008	399.7	23.18084	-0.74357	21.99632
3.7	36.4	-0.26217	0.02112	-0.24105	436.1	22.91866	-0.72245	21.75527
3.8	22.4	-0.14551	0.02112	-0.12438	458.5	22.77316	-0.70132	21.63089
3.9/4	3.2	-0.02277	0.01682	-0.00595	461.7	22.75038	-0.68450	21.62494
3.10	3.8	-0.00996	0.00054	-0.00942	465.5	22.74042	-0.68396	21.61552
4.1	5	-0.04162	0.00006	-0.04156	470.5	22.69880	-0.68390	21.57396
4.2	13.4	-0.10495	0.00345	-0.10150	483.9	22.59385	-0.68045	21.47246
4.3	6.4	-0.04157	0.00604	-0.03554	490.3	22.55228	-0.67441	21.43692
4.4	5.3	-0.04392	-0.00259	-0.04651	495.6	22.50836	-0.67700	21.39041
4.5	19.2	-0.15832	0.00106	-0.15726	514.8	22.35004	-0.67595	21.23315
4.6	3.8	0.97977	0.24198	1.22176	518.6	23.32981	-0.43396	22.45490
4.7	3.8	0.05149	0.04268	0.09417	522.4	23.38130	-0.39128	22.54908

Table 4.3: IBM PS/2 Call Sheet, Arbitrary Order, EcoFactor 1

CALL SHEET, ECOFACTOR:1

Optimized Disassembly Order

Part #	Time	Profit Effect	MET Effect	Eco\$ Effect	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)
1.0	0	-0.71771	-9.3467	-10.0644	0	-0.71771	-9.3467	-10.0644
1.1	20.2	-0.16833	0	-0.16833	20.2	-0.88604	-9.3467	-10.2327
1.2/2	4.2	0.026556	-0.03567	-0.00912	24.4	-0.85949	-9.38237	-10.2419
3.5	8.8	15.03227	1.523009	16.55528	33.2	14.17278	-7.85936	6.31342
3.2	8.8	5.014667	1.265236	6.279903	42	19.18745	-6.59412	12.59332
3.6	3.2	0.129963	0.470117	0.60008	45.2	19.31741	-6.12401	13.1934
1.7	21.3	-0.17498	0.001584	-0.1734	66.5	19.14243	-6.12242	13.02001
1.8	4.2	2.097	1.498513	3.595513	70.7	21.23943	-4.62391	16.61552
1.6/3	12	-0.081	0.07944	-0.00156	82.7	21.15843	-4.54447	16.61396
3.1	8.8	0.936187	0.062971	0.999158	91.5	22.09462	-4.4815	17.61312
1.9	21.3	-0.17638	0.000704	-0.17568	112.8	21.91824	-4.48079	17.43745
1.10	21.3	-0.17638	0.000704	-0.17568	134.1	21.74186	-4.48009	17.26177
1.11	3.9	0.689567	2.072394	2.761961	138	22.43143	-2.4077	20.02373
3.9/4	3.2	-0.02277	0.016822	-0.00595	141.2	22.40865	-2.39087	20.01778
4.4	5.3	-0.04392	-0.00259	-0.04651	146.5	22.36473	-2.39346	19.97127
4.5	19.2	-0.15832	0.001056	-0.15726	165.7	22.20641	-2.3924	19.81401
4.6	3.8	0.982507	0.2457	1.228206	169.5	23.18892	-2.1467	21.04221
3.3	3.2	-0.02648	0.000117	-0.02636	172.7	23.16244	-2.14659	21.01585
3.4	3.8	0.040884	0.169646	0.21053	176.5	23.20332	-1.97694	21.22638
2.1	10	-0.08333	5.55E-17	-0.08333	186.5	23.11999	-1.97694	21.14305
2.2	13.4	-0.01026	0.04971	0.039448	199.9	23.10973	-1.92723	21.1825
2.3	8.8	0.271769	0.169175	0.440944	208.7	23.3815	-1.75806	21.62344
1.14	13.6	-0.11305	0.000329	-0.11272	222.3	23.26845	-1.75773	21.51072
1.15	3.8	-0.03138	0.000302	-0.03108	226.1	23.23706	-1.75742	21.47964
1.16	3.8	-0.02854	0.003324	-0.02521	229.9	23.20853	-1.7541	21.45443
1.17	7.8	-0.06472	0.000302	-0.06441	237.7	23.14381	-1.7538	21.39001
1.18	3.8	0.469702	0.007803	0.477505	241.5	23.61351	-1.746	21.86752
1.3	6.4	-0.04629	0.004872	-0.04142	247.9	23.56722	-1.74112	21.8261
1.4	21.9	-0.18037	0.002267	-0.1781	269.8	23.38685	-1.73886	21.648
1.12	5.6	-0.04183	0.005138	-0.03669	275.4	23.34502	-1.73372	21.6113
1.13	3.2	-0.02384	0.00203	-0.02181	278.6	23.32118	-1.73169	21.58949
1.19	3.8	-0.03003	0.000802	-0.02923	282.4	23.29115	-1.73089	21.56026
1.20	5	-0.04167	0	-0.04167	287.4	23.24948	-1.73089	21.5186
1.21	15	-0.125	0	-0.125	302.4	23.12448	-1.73089	21.3936
1.22	34.8	-0.29	0	-0.29	337.2	22.83448	-1.73089	21.1036
1.23	41.4	-0.345	0	-0.345	378.6	22.48948	-1.73089	20.7586
1.24	20	-0.16667	0	-0.16667	398.6	22.32282	-1.73089	20.59193
1.25	3.8	1.407622	0.705564	2.113187	402.4	23.73044	-1.02532	22.70512
2.4	25	-0.20691	0.001644	-0.20527	427.4	23.52353	-1.02368	22.49985
2.5	3.8	0.124778	0.166222	0.291	431.2	23.64831	-0.85746	22.79085
4.1	5	-0.04167	1.39E-17	-0.04167	436.2	23.60664	-0.85746	22.74918
4.2	13.4	-0.10512	0.003207	-0.10192	449.6	23.50152	-0.85425	22.64727
4.3	6.4	-0.04188	0.005612	-0.03627	456	23.45963	-0.84864	22.611
4.7	3.8	0.049293	0.039688	0.088981	459.8	23.50892	-0.80895	22.69998
3.7	36.4	-0.26326	0.019644	-0.24362	496.2	23.24566	-0.7893	22.45636
3.8	22.4	-0.1466	0.019644	-0.12695	518.6	23.09907	-0.76966	22.32941
3.10	3.8	-0.03167	0	-0.03167	522.4	23.0674	-0.76966	22.29774

Table 4.4: IBM PS/2 Call Sheet, Optimized Order, EcoFactor 1

CALL SHEET, ECOFACTOR:4
Arbitrary Disassembly Order

Part #	Dis Time	Profit Effect	MET Effect	Eco\$ Effect	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)
1.0	0.0	-0.71771	-9.34670	-38.10449	0.0	-0.71771	-9.34670	-38.10449
1.1	20.2	-0.16833	0.00000	-0.16833	20.2	-0.88604	-9.34670	-38.27283
1.2/2	4.2	0.02656	-0.03567	-0.11613	24.4	-0.85949	-9.38237	-38.38896
1.3	6.4	-0.04549	0.00435	-0.02811	30.8	-0.90498	-9.37802	-38.41706
1.4	21.9	-0.17970	0.00156	-0.17346	52.7	-1.08468	-9.37646	-38.59052
1.6/3	12.0	-0.03343	0.32500	1.26657	64.7	-1.11811	-9.05146	-37.32395
1.7	21.3	-0.17498	0.00158	-0.16864	86.0	-1.29309	-9.04987	-37.49259
1.8	4.2	2.09700	1.49851	8.09105	90.2	0.80391	-7.55136	-29.40154
1.9	21.3	-0.17638	0.00070	-0.17356	111.5	0.62753	-7.55066	-29.57511
1.10	21.3	-0.17638	0.00070	-0.17356	132.8	0.45115	-7.54995	-29.74867
1.11	3.9	0.68810	2.07363	8.98260	136.7	1.13925	-5.47633	-20.76607
1.12	5.6	-0.04183	0.00514	-0.02128	142.3	1.09741	-5.47119	-20.78735
1.13	3.2	-0.02384	0.00203	-0.01572	145.5	1.07357	-5.46916	-20.80307
1.14	13.6	-0.11305	0.00033	-0.11173	159.1	0.96053	-5.46883	-20.91480
1.15	3.8	-0.03138	0.00030	-0.03017	162.9	0.92914	-5.46853	-20.94497
1.16	3.8	-0.02854	0.00332	-0.01524	166.7	0.90061	-5.46520	-20.96021
1.17	7.8	-0.06472	0.00030	-0.06351	174.5	0.83589	-5.46490	-21.02372
1.18	3.8	0.46970	0.00780	0.50091	178.3	1.30559	-5.45710	-20.52281
1.19	3.8	-0.03003	0.00080	-0.02682	182.1	1.27556	-5.45630	-20.54963
1.20	5.0	-0.04167	0.00000	-0.04167	187.1	1.23389	-5.45630	-20.59130
1.21	15.0	-0.12500	0.00000	-0.12500	202.1	1.10889	-5.45630	-20.71630
1.22	34.8	-0.29000	0.00000	-0.29000	236.9	0.81889	-5.45630	-21.00630
1.23	41.4	-0.34500	0.00000	-0.34500	278.3	0.47389	-5.45630	-21.35130
1.24	20.0	-0.16667	0.00000	-0.16667	298.3	0.30723	-5.45630	-21.51796
1.25	3.8	1.40762	0.70556	4.22988	302.1	1.71485	-4.75073	-17.28808
2.1	10.0	-0.08333	0.00000	-0.08333	312.1	1.63152	-4.75073	-17.37142
2.2	13.4	-0.01026	0.04971	0.18858	325.5	1.62125	-4.70102	-17.18284
2.3	8.8	0.27177	0.16918	0.94847	334.3	1.89302	-4.53185	-16.23437
2.4	25.0	-0.20691	0.00164	-0.20033	359.3	1.68611	-4.53020	-16.43470
2.5	3.8	0.12478	0.16622	0.78967	363.1	1.81089	-4.36398	-15.64503
3.1	8.8	0.93619	0.06297	1.18807	371.9	2.74708	-4.30101	-14.45696
3.2	8.8	5.01467	1.26524	10.07561	380.7	7.76174	-3.03577	-4.38135
3.3	3.2	-0.02648	0.00012	-0.02601	383.9	7.73526	-3.03566	-4.40736
3.4	3.8	0.01157	0.12978	0.53070	387.7	7.74684	-2.90587	-3.87666
3.5	8.8	15.03227	1.52301	21.12430	396.5	22.77910	-1.38287	17.24764
3.6	3.2	0.12996	0.47012	2.01043	399.7	22.90907	-0.91275	19.25807
3.7	36.4	-0.26217	0.02112	-0.17768	436.1	22.64689	-0.89162	19.08040
3.8	22.4	-0.14551	0.02112	-0.06101	458.5	22.50139	-0.87050	19.01939
3.9/4	3.2	-0.02277	0.01682	0.04451	461.7	22.47861	-0.85368	19.06390
3.10	3.8	-0.00996	0.00054	-0.00779	465.5	22.46865	-0.85313	19.05611
4.1	5.0	-0.04162	0.00006	-0.04138	470.5	22.42703	-0.85307	19.01473
4.2	13.4	-0.10495	0.00345	-0.09115	483.9	22.32208	-0.84963	18.92358
4.3	6.4	-0.04157	0.00604	-0.01743	490.3	22.28051	-0.84359	18.90615
4.4	5.3	-0.04392	-0.00259	-0.05427	495.6	22.23659	-0.84618	18.85188
4.5	19.2	-0.15832	0.00106	-0.15410	514.8	22.07827	-0.84512	18.69779
4.6	3.8	0.97977	0.24198	1.94770	518.6	23.05804	-0.60314	20.64549
4.7	3.8	0.05149	0.04268	0.22221	522.4	23.10954	-0.56046	20.86770

Table 4.5 IBM PS/2 Call Sheet, Optimized Order, EcoFactor 4

CALL SHEET, ECOFACTOR:3
Optimized Disassembly Order

Part #	Dis Time	Profit Effect	MET Effect	Eco\$ Effect	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)
1.0	0	-1.46561	-14.2931	-44.3448	0	-1.46561	-14.2931	-44.3448
1.14/10	29.5	-0.19977	-0.00777	-0.22308	29.5	-1.66538	-14.3008	-44.5678
1.32	27	-0.22399	0.000373	-0.22287	56.5	-1.88936	-14.3005	-44.7907
1.33	5.4	200.0364	1.4628	204.4248	61.9	198.1471	-12.8377	159.6341
1.17	16.7	134.8839	0.315251	135.8297	78.6	333.031	-12.5224	295.4638
10.4	3.2	9.988733	0.265369	10.78484	81.8	343.0198	-12.257	306.2487
10.9	3.2	9.975356	0.035075	10.08058	85	352.9951	-12.222	316.3293
10.3	3.8	45.0584	1.035741	48.16562	88.8	398.0535	-11.1862	364.4949
1.19	17.5	34.89866	0.422688	36.16672	106.3	432.9522	-10.7635	400.6616
1.34	6.4	-0.01013	0.030347	0.080907	112.7	432.942	-10.7332	400.7425
1.35	49.2	-0.40848	0.00056	-0.4068	161.9	432.5336	-10.7326	400.3357
1.36	4.8	35.08622	0.381602	36.23102	166.7	467.6198	-10.351	436.5667
1.10	41.4	-0.34399	0.000373	-0.34287	208.1	467.2758	-10.3506	436.2239
1.11/3	10.1	-0.0534	-0.0041	-0.0657	218.2	467.2224	-10.3547	436.1582
1.20	12.8	-0.09803	0.006069	-0.07982	231	467.1244	-10.3487	436.0783
1.22	9.6	-0.0728	0.005058	-0.05763	240.6	467.0516	-10.3436	436.0207
1.23	11.2	-0.09333	0	-0.09333	251.8	466.9582	-10.3436	435.9274
1.43	3.9	-0.02335	0.006216	-0.00471	255.7	466.9349	-10.3374	435.9227
1.44	3.8	-0.03108	0.000218	-0.03042	259.5	466.9038	-10.3372	435.8923
1.45	3.9	-0.02335	0.006216	-0.00471	263.4	466.8805	-10.331	435.8876
1.46	3.8	-0.03108	0.000218	-0.03042	267.2	466.8494	-10.3308	435.8571
1.47	96.3	-0.8025	0	-0.8025	363.5	466.0469	-10.3308	435.0546
1.51	6.7	150.1892	2.552997	157.8482	370.2	616.2361	-7.77775	592.9028
1.37	8.8	0.049227	0.024342	0.122252	379	616.2853	-7.75341	593.025
1.25/22	10.1	-0.08078	-0.00045	-0.08213	389.1	616.2045	-7.75386	592.9429
1.1/2	9	0.24112	-0.5597	-1.43799	398.1	616.4456	-8.31357	591.5049
1.2	11.6	-0.04838	0.012743	-0.01015	409.7	616.3972	-8.30082	591.4948
1.3	9.3	-0.0775	0	-0.0775	419	616.3197	-8.30082	591.4173
1.4	10.1	-0.06014	0.017257	-0.00837	429.1	616.2596	-8.28357	591.4089
1.5	5	-0.04055	0.000623	-0.03868	434.1	616.219	-8.28294	591.3702
1.6	10.1	-0.06014	0.017257	-0.00837	444.2	616.1589	-8.26569	591.3618
1.7	5	-0.04055	0.000623	-0.03868	449.2	616.1184	-8.26507	591.3232
1.8	10	-0.08323	0.000245	-0.08249	459.2	616.0351	-8.26482	591.2407
1.12	20.4	-0.16505	0.003553	-0.15439	479.6	615.8701	-8.26127	591.0863
1.13/7	3.8	-0.03167	1.78E-15	-0.03167	483.4	615.8384	-8.26127	591.0546
1.24/21	4.8	-0.04	0	-0.04	488.2	615.7984	-8.26127	591.0146
1.26/24	10.1	-0.08417	0	-0.08417	498.3	615.7142	-8.26127	590.9304
1.27	32.1	-0.26686	0.00074	-0.26464	530.4	615.4474	-8.26053	590.6658
1.28	3.8	-0.00685	0.026369	0.072258	534.2	615.4405	-8.23416	590.7381
1.29	18	-0.14788	0.001523	-0.14331	552.2	615.2927	-8.23264	590.5948
1.30	6	-0.04929	0.000508	-0.04777	558.2	615.2434	-8.23213	590.547
1.31	22.8	-0.17886	0.017099	-0.12757	581	615.0645	-8.21503	590.4194
1.38	13.4	-0.10743	0.003045	-0.09829	594.4	614.9571	-8.21198	590.3211
1.39	7.6	-0.05909	0.003045	-0.04996	602	614.898	-8.20894	590.2712
1.40	3.2	-0.02667	0	-0.02667	605.2	614.8713	-8.20894	590.2445
1.41	13.5	-0.10693	0.008549	-0.08128	618.7	614.7644	-8.20039	590.1632
1.42	13.5	-0.10693	0.008549	-0.08128	632.2	614.6575	-8.19184	590.0819
1.52	4.8	300.3286	5.686551	317.3882	637	914.986	-2.50529	907.4702
21.4	3.8	0.108253	0.100496	0.409741	640.8	915.0943	-2.40479	907.8799
22.1	3.8	-0.01725	0.003071	-0.00804	644.6	915.077	-2.40172	907.8719
22.2	3.8	0.114613	0.105064	0.429805	648.4	915.1917	-2.29666	908.3017
3.1	3.8	-0.00897	0.004835	0.005531	652.2	915.1827	-2.29182	908.3072
3.2	5	0.067761	0.078595	0.303546	657.2	915.2504	-2.21323	908.6108
3.3	10	-0.07843	0.002405	-0.07121	667.2	915.172	-2.21082	908.5395

Table 4.6 C/K Dash Call Sheet, Optimized Order, EcoFactor 3 (1 of 2)

CALL SHEET, ECOFACTOR:3

Optimized Disassembly Order

Part #	Dis Time	Profit Effect	MET Effect	Eco\$ Effect	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)
3.4	3.8	0.032938	0.03167	0.127948	671	915.205	-2.17915	908.6675
3.5	5	-0.04167	-2.2E-16	-0.04167	676	915.1633	-2.17915	908.6258
3.6	5	-0.04167	2.22E-16	-0.04167	681	915.1216	-2.17915	908.5842
3.7	69.3	-0.56033	0.008419	-0.53507	750.3	914.5613	-2.17073	908.0491
3.8	41	-0.34167	0	-0.34167	791.3	914.2196	-2.17073	907.7074
3.9	3.8	-0.03167	2.22E-16	-0.03167	795.1	914.188	-2.17073	907.6758
3.10	3.8	1.320187	0.970954	4.233048	798.9	915.5081	-1.19978	911.9088
21.8	8.2	-0.06791	0.000493	-0.06643	807.1	915.4402	-1.19929	911.8424
21.9	5	-0.04145	0.000491	-0.03998	812.1	915.3988	-1.1988	911.8024
21.10	3.8	0.127333	0.1142	0.469933	815.9	915.5261	-1.0846	912.2723
21.1	5	-0.04161	0.000123	-0.04125	820.9	915.4845	-1.08447	912.2311
21.2	12.4	-0.10312	0.000247	-0.10238	833.3	915.3814	-1.08423	912.1287
21.3	3.8	-0.02847	0.0034	-0.01827	837.1	915.3529	-1.08083	912.1104
21.7	12.2	-0.10124	0.000493	-0.09976	849.3	915.2517	-1.08033	912.0107
21.11	3.8	0.127333	0.1142	0.469933	853.1	915.379	-0.96613	912.4806
8.1	6.4	-0.05333	2.78E-17	-0.05333	859.5	915.3257	-0.96613	912.4273
8.2	5	-0.0409	0.001758	-0.03563	864.5	915.2848	-0.96438	912.3917
8.3	14.8	-0.12333	-2.8E-17	-0.12333	879.3	915.1614	-0.96438	912.2683
8.4	3.2	-0.02455	0.001523	-0.01998	882.5	915.1369	-0.96285	912.2483
8.5	6.4	-0.05328	0.000123	-0.05291	888.9	915.0836	-0.96273	912.1954
8.6	5	-0.04167	2.78E-17	-0.04167	893.9	915.042	-0.96273	912.1538
8.7	5	-0.04167	-2.8E-17	-0.04167	898.9	915.0003	-0.96273	912.1121
8.8	3.8	0.146413	0.127904	0.530125	902.7	915.1467	-0.83483	912.6422
24.1	3.8	0.029107	0.04365	0.160056	906.5	915.1758	-0.79118	912.8023
24.2	8.8	-0.06839	0.003553	-0.05773	915.3	915.1074	-0.78762	912.7445
24.3	3.2	-0.02575	0.000196	-0.02516	918.5	915.0817	-0.78743	912.7194
24.4	3.8	-0.01725	0.003071	-0.00804	922.3	915.0644	-0.78436	912.7113
24.5	5	-0.03955	0.001523	-0.03498	927.3	915.0249	-0.78283	912.6764
24.6	0	0.02968	0.021317	0.093632	927.3	915.0546	-0.76152	912.77
24.7	0	0.00212	0.001523	0.006688	927.3	915.0567	-0.75999	912.7767
7.1	5	-0.02695	0.007216	-0.0053	932.3	915.0297	-0.75278	912.7714
7.2/8	3.8	-0.03167	-5.6E-17	-0.03167	936.1	914.9981	-0.75278	912.7397
7.3	3.8	-0.03145	0.000227	-0.03077	939.9	914.9666	-0.75255	912.709
7.4	8.2	-0.06791	0.000493	-0.06643	948.1	914.8987	-0.75206	912.6425
7.5	3.8	0.051013	0.059384	0.229165	951.9	914.9497	-0.69267	912.8717
7.6	3.8	-0.03167	0	-0.03167	955.7	914.918	-0.69267	912.84
7.7	11.3	-0.09395	0.000247	-0.09321	967	914.8241	-0.69243	912.7468
7.8	3.8	-0.03167	0	-0.03167	970.8	914.7924	-0.69243	912.7151
7.9	3.8	-0.03167	-5.6E-17	-0.03167	974.6	914.7608	-0.69243	912.6835
7.10	37	-0.30748	0.000987	-0.30452	1011.6	914.4533	-0.69144	912.379
7.11	3.8	-0.01858	0.006414	0.00066	1015.4	914.4347	-0.68503	912.3796
7.12	37	-0.30748	0.000987	-0.30452	1052.4	914.1272	-0.68404	912.0751
7.13	3.8	-0.01858	0.006414	0.00066	1056.2	914.1086	-0.67763	912.0758
7.15	3.8	0.169027	0.144146	0.601464	1060	914.2777	-0.53348	912.6772
2.1	5	-0.04165	-5.8E-06	-0.04167	1065	914.236	-0.53349	912.6356
2.2	7.8	-0.06475	7.33E-05	-0.06453	1072.8	914.1713	-0.53341	912.571
2.3	31.2	-0.25984	-3.9E-05	-0.25996	1104	913.9114	-0.53345	912.3111
2.4	5	-0.03627	0.002891	-0.02759	1109	913.8752	-0.53056	912.2835
2.5	3.8	0.025573	0.041112	0.148909	1112.8	913.9007	-0.48945	912.4324

Table 4.6 C/K Dash Call Sheet, Optimized Order, EcoFactor 3 (2 of 2)

IBM PS/2, Optimized Disassembly Sequence: Eco\$ Graph (EcoFactor:1)

Figure 4.1
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IBM PS/2, Arbitrary Disassembly Sequence: Combined Financial, Environmental, and Eco\$ Graph
(EcoFactor:1)

Figure 4.2
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IBM PS/2, Optimized Disassembly Sequence: Combined Financial, Environmental, and Eco\$ Graph
(EcoFactor:1)

Figure 4.3
140

IBM PS/2, Eco\$ Comparison of Arbitrary and Optimized Disassembly Sequences (EcoFactor:1)

Figure 4.4
141

IBM PS/2, Optimized Disassembly Sequence: Eco\$ Graph (EcoFactor:4)

Figure 4.5
142

IBM PS/2, Optimized Disassembly Sequence: Combined Financial, Environmental, and Eco\$ Graph
(EcoFactor:4)

Figure 4.6
143

IBM PS/2, Eco\$ Comparison of Arbitrary and Optimized Disassembly Sequences (EcoFactor:4)

GM C/K Truck Dash, Optimized Disassembly Sequence: Combined Financial, Environmental, and Eco\$
Graph (EcoFactor: 3)

Figure 4.8
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GM C/K Truck Dash, Optimized Disassembly Sequence: Eco\$ Graph (EcoFactor: 3)

Figure 4.9
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GM C/K Truck Dash, Eco\$ Comparison of Arbitrary and Optimized Disassembly Sequences Graph
(EcoFactor: 3)

Figure 4.10
147

GM C/K Truck Dash, Optimized Disassembly Sequence, No Reuse: Eco\$ Graph (EcoFactor: 3)

Figure 4.11
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GM C/K Truck Dash, Optimized Disassembly Sequence, No Reuse: Combined Financial, Environmental, and Eco\$ Graph (EcoFactor: 3)

Figure 4.12
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Chapter 5: Conclusions and Recommendations

5.1 Conclusions

The environmental impact of product manufacture is one of the many factors manufacturers must deal with. New pieces of environmental legislation are being passed every day in this country, and the manufacturers of this country must plan ahead to cope with new legal demands.

Environmental policies around the world are becoming stricter. Companies that wish to sell their products to a global market must meet the environmental standards of each of the countries they do business in. This requires a product that is designed to be “green,” as well as a systematic plan to deal with that product once it has reached the end of its useful life. Germany, with 80 million consumers, is Europe’s largest market. Germany has leapt ahead of the pack with some of the strictest environmental laws pertaining to products in the world. Product take-back in Germany, including end of life automobiles, electronics equipment, and packaging, is now the law of the land. It is up to manufacturers to meet the goals set by the German government if they wish to sell their goods there.

There are alternatives to disposal for products once they reach their end of life phase. Opportunities for recycling and reuse exist for many materials and components. Judicious planning by manufacturers can maximize these

opportunities. Companies like Xerox have shown that planning for material recovery opportunities in end of life product can reap huge profits.

Through the case studies developed for the present work, it has been shown that using the presented financial/environmental optimization methods, the environmental impact of products can be reduced while the profit that can be extracted from disassembly is maximized. The present work introduced the concept of an Eco\$. This single figure represents the joint financial and environmental aspects of the components of a product. The Eco\$ uses a weighting factor to normalize the environmental effects of disassembly to a dollar figure. Several methods for determining this eco-factor have been presented.

The disassembly of each of the case studies gave positive net results financially and environmentally. At the point of maximum Eco\$ profit, 22.79 Eco\$ of value was removed from the IBM PS/2, translating into a \$23.65 financial profit and a MET value improvement of 8.49 MET points representing a 91% improvement over landfilling without disassembly. For the General Motors C/K truck dashboard, a maximum Eco\$ return of 912.87 Eco\$ was realized, translating into a financial profit of \$914.95 and a 95% improvement of 13.60 MET points. Thus it has been shown that the disassembly of end of life products can be profitable both environmentally and financially, and proper planning can increase the profits realized from disassembly.

The Eco\$ optimization methods presented in this work have been proven to increase the rate at which environmental and financial value can be recovered

during the disassembly of an end of life product. For the dashboard optimized disassembly order, it was determined that 14777 Eco\$/hour could be gained from disassembly, as opposed to the maximum return rate of 4816 Eco\$/hour for the arbitrary disassembly sequence.

5.2 Recommendations for Future Work

While the DFDE worksheet represents a considerable improvement in disassembly analysis tools, it is not the optimal tool for disassembly sequence generation. The workbook greatly reduces the amount of manual entries and manipulation necessary to analyze a product, however, disassembly sequence generation still requires a great deal of manual manipulation. It is suggested that an automatic sequence generation algorithm be created to speed this process. This tool would most likely not be a Microsoft Excel application.

Further research is suggested into the determination of a universal eco-factor. The literature search for the present work did not uncover a likely candidate eco-factor. In fact, the literature search revealed that little to no work has been carried out in this area. Determination of a universal eco-factor would be a large scale project, most likely beyond the scope of a master's thesis topic.

Similarly, the conversion of the MET point values for the Netherlands to United States values is suggested. The literature search did not reveal the comprehensive national environmental impact figures necessary to complete this

task. Finding the national contributions to each of the eight environmental problems considered in MET point generation would most likely be beyond the scope of a master's thesis topic as well.

Appendix A

Macro Code and Logical Operations

- A1 DFDE "SEARCH ALL" Macro Code**
- A2 DFDE "SEARCH RANGE" Macro Code**
- A3 MET Rest Logical Operations Pseudo-Code**
- A4 Rest Disp \$ Logical Operations Pseudo-Code**
- A5 Profit (step) Logical Operations Pseudo-Code**
- A6 MET (step) Logical Operations Pseudo-Code**

A1 DFDE "SEARCH ALL" Macro Code

```
Sub GoFindIT()
```

```
  Sheets("DFDE Worksheet").Select
```

```
    Range("I9").Select
```

```
Do
```

```
On Error Resume Next
```

```
ActiveCell.Offset(0, 7).Select
```

```
  mymatl = ActiveCell.Formula
```

```
  If mymatl = "" Then
```

```
    mymatl = 0
```

```
  End If
```

```
  ActiveCell.Offset(0, 1).Select
```

```
  myproc = ActiveCell.Formula
```

```
  If myproc = "" Then
```

```
    myproc = 0
```

```
  End If
```

```
  ActiveCell.Offset(0, 2).Select
```

```
  destcode = ActiveCell.Formula
```

```
Worksheets("Material Codes").Select
```

```
  Columns("A:A").Select
```

```

Selection.Find(What:=mymatl, After:=ActiveCell, LookIn:=xlFormulas, _
    LookAt:=xlPart, SearchOrder:=xlByRows, SearchDirection:=xlNext _
    , MatchCase:=False).Activate
ActiveCell.Offset(0, 2).Activate
myconvrate = ActiveCell.Formula
ActiveCell.Offset(0, 2).Select
metrec = ActiveCell.Formula
ActiveCell.Offset(0, 1).Select
myrecreate = ActiveCell.Formula
ActiveCell.Offset(0, 1).Select
metldnor = ActiveCell.Formula
ActiveCell.Offset(0, 1).Select
metldspe = ActiveCell.Formula
ActiveCell.Offset(0, 1).Select
metincnor = ActiveCell.Formula
ActiveCell.Offset(0, 1).Select
metincspe = ActiveCell.Formula

```

```

Worksheets("Process Codes").Select

```

```

Columns("A:A").Select

```

```

Selection.Find(What:=myproc, After:=ActiveCell, LookIn:=xlFormulas, _
    LookAt:=xlPart, SearchOrder:=xlByRows, SearchDirection:=xlNext _

```

```
    , MatchCase:=False).Activate  
ActiveCell.Offset(0, 3).Select  
myprocrate = ActiveCell.Formula
```

```
Worksheets("DFDE Worksheet").Select
```

```
ActiveCell.Offset(0, -4).Activate  
myweight = ActiveCell.Formula
```

```
If myweight = "" Then
```

```
    myweight = 0
```

```
End If
```

```
ActiveCell.Offset(0, 3).Activate  
myprocfact = ActiveCell.Formula
```

```
ActiveCell.Offset(0, 3).Select
```

```
ActiveCell.Formula = "=" + myconvrate + "*" + myweight
```

```
ActiveCell.Offset(0, 1).Select
```

```
ActiveCell.Formula = "=" + myprocrate + "*" + myprocfact
```

```
ActiveCell.Offset(0, 1).Select
```

```
ActiveCell.Formula = "=" + metrec + "*" + myweight
```

```
ActiveCell.Offset(0, 1).Select
```

```
ActiveCell.Formula = "=" + metldnor + "*" + myweight
```

```
ActiveCell.Offset(0, 1).Select
```

```
ActiveCell.Formula = "=" + metincnor + "*" + myweight
```



```
ActiveCell.Offset(0, 1).Select
ActiveCell.Formula = "=" + metldspe + "*" + myweight
ActiveCell.Offset(0, 1).Select
ActiveCell.Formula = "=" + metincspe + "*" + myweight
ActiveCell.Offset(0, 1).Select
ActiveCell.Formula = "=" + myrecrate + "*" + myweight
ActiveCell.Offset(1, -19).Select

Count = Count + 1

Loop Until ActiveCell.Formula = ""

Range("A1").Select

End Sub
```

A2 DFDE "SEARCH RANGE" Macro Code

```
Sub searchone()
```

```
    With Application
```

```
        .Calculation = xlManual
```

```
    End With
```

```
    Sheets("DFDE Worksheet").Select
```

```
    For Each cell In Selection
```

```
        tempt = ActiveCell.Address(rowabsolute:=False, columnabsolute:=False)
```

```
        righttext = Right(tempt, Len(tempt) - 1)
```

```
        Cells(righttext, 1).Select
```

```
    On Error Resume Next
```

```
    ActiveCell.Offset(0, 7).Select
```

```
        mymatl = ActiveCell.Formula
```

```
        If mymatl = "" Then
```

```
            mymatl = 0
```

```
        End If
```

```
    ActiveCell.Offset(0, 1).Select
```

```
    myproc = ActiveCell.Formula
```

If myproc = "" Then

 myproc = 0

End If

ActiveCell.Offset(0, 2).Select

destcode = ActiveCell.Formula

Worksheets("Material Codes").Select

Columns("A:A").Select

Selection.Find(What:=mymatl, After:=ActiveCell, LookIn:=xlFormulas, _

 LookAt:=xlPart, SearchOrder:=xlByRows, SearchDirection:=xlNext _

 , MatchCase:=False).Activate

ActiveCell.Offset(0, 2).Activate

myconvrate = ActiveCell.Formula

ActiveCell.Offset(0, 2).Select

metrec = ActiveCell.Formula

ActiveCell.Offset(0, 1).Select

myrecreate = ActiveCell.Formula

ActiveCell.Offset(0, 1).Select

metldnor = ActiveCell.Formula

ActiveCell.Offset(0, 1).Select

metldspe = ActiveCell.Formula

ActiveCell.Offset(0, 1).Select

metincnor = ActiveCell.Formula

ActiveCell.Offset(0, 1).Select

metincspe = ActiveCell.Formula

Worksheets("Process Codes").Select

Columns("A:A").Select

Selection.Find(What:=myproc, After:=ActiveCell, LookIn:=xlFormulas, _

LookAt:=xlPart, SearchOrder:=xlByRows, SearchDirection:=xlNext _

, MatchCase:=False).Activate

ActiveCell.Offset(0, 3).Select

myprocrate = ActiveCell.Formula

Worksheets("DFDE Worksheet").Select

ActiveCell.Offset(0, -4).Activate

myweight = ActiveCell.Formula

If myweight = "" Then

myweight = 0

End If

ActiveCell.Offset(0, 3).Activate

myprocfact = ActiveCell.Formula

ActiveCell.Offset(0, 3).Select

ActiveCell.Formula = "=" + myconvrate + "*" + myweight

```

ActiveCell.Offset(0, 1).Select

ActiveCell.Formula = "=" + myprocrate + "*" + myprocfact

ActiveCell.Offset(0, 1).Select

ActiveCell.Formula = "=" + metrec + "*" + myweight

ActiveCell.Offset(0, 1).Select

ActiveCell.Formula = "=" + metldnor + "*" + myweight

ActiveCell.Offset(0, 1).Select

ActiveCell.Formula = "=" + metincnor + "*" + myweight

ActiveCell.Offset(0, 1).Select

ActiveCell.Formula = "=" + metldspe + "*" + myweight

ActiveCell.Offset(0, 1).Select

ActiveCell.Formula = "=" + metincspe + "*" + myweight

ActiveCell.Offset(0, 1).Select

ActiveCell.Formula = "=" + myrecrate + "*" + myweight

ActiveCell.Offset(1, -19).Select

Count = Count + 1

Next

Range("A1").Select

    With Application

        .Calculation = xlAutomatic

    End With

End Sub

```

A3 MET Rest Logical Operations Pseudo-Code

For any step (n):

$$\text{MET Rest} = \sum_{k=n+1}^{\text{Worksheet End}} (\text{MET Conv} + \text{MET Prod})_k + \sum_{k=n+1}^{\text{Worksheet End}} (\text{MET EOL??})_k$$

Where $(\text{MET EOL??})_k =$

IF {Toxic Rest? = "y", THEN

IF [Rest Default S = "f", THEN

$$(\text{MET EOL??})_k = (\text{MET EOL SI})_k$$

$$\text{ELSE } (\text{MET EOL??})_k = (\text{MET EOL SL})_k]$$

ELSE IF [Rest Default N = "e", THEN

$$(\text{MET EOL??})_k = (\text{MET EOL NI})_k$$

$$\text{ELSE } (\text{MET EOL??})_k = (\text{MET EOL NR})_k]}$$

A4 Rest Disp \$ Logical Operations Pseudo-Code

For any step (n):

$$\text{Rest Disp \$} = \sum_{k=n+1}^{\text{Worksheet End}} (\text{Part(s) Wt.})_k \times (\text{Rest Disp Rate??})$$

Where Rest Disp Rate??=

IF{Toxic Rest? = "y", THEN

IF [Rest Default S = "f", THEN

Rest Disp Rate??= Special Incin Rate, \$/kg

ELSE Rest Disp Rate?? = Special LF Rate, \$/kg

ELSE IF[Rest Default N = "e", THEN

Rest Disp Rate?? =Regular Incin Rate, \$/kg

ELSE Rest Disp Rate?? =Regular LF Rate, \$/kg}}

A5 Profit (step) Logical Operations and Pseudo-Code

For any step (n):

$\text{Profit}(\text{step})_n = -(\text{Dis Time}_n \times \text{Labor Rate}/3600) +$

IF(Dest Code_n="a", THEN

0

ELSE IF (Dest Code_n="b", THEN

Rec\$_n

ELSE IF (Dest Code_n="c", THEN

Part(s)Wt._n*Regular LF Rate, \$/kg

ELSE IF (Dest Code_n="d", THEN

Part(s)Wt._n*Special LF Rate, \$/kg

ELSE IF (Dest Code_n="e", THEN

Part(s)Wt._n*Normal Incin Rate, \$/kg

ELSE IF (Dest Code_n="f", THEN

Part(s)Wt._n*Special Incin Rate, \$/kg

ELSE Dest Code_n))))))

A6 MET (step) Logical Operations and Pseudo-Code

For any step (n):

MET(step)_n= IF(Dest Code_n="a", THEN

0

ELSE IF (Dest Code_n="b", THEN

-MET Conv_n - MET Rec_n

ELSE IF (Dest Code_n="c", THEN

-MET Conv_n - MET Proc_n - MET EOL NL_n

ELSE IF (Dest Code_n="d", THEN

-MET Conv_n - MET Proc_n - MET EOL SL_n

ELSE IF (Dest Code_n="e", THEN

-MET Conv_n - MET Proc_n - MET EOL NI_n

ELSE IF (Dest Code_n="f", THEN

-MET Conv_n - MET Proc_n - MET EOL SI_n

ELSE 0))))))

Appendix B

IBM PS/2 Assembly Drawings

- B1 Exploded Subassembly Diagram**
- B2 Cooling Fan Subassembly**
- B3 Cover Subassembly**
- B4 Drive Bracket Subassembly**
- B5 Main Assembly**

B1 Exploded Subassembly Diagram

- 1 Cooling Fan Subassembly
- 2 Cover Subassembly
- 3 Drive Bracket Subassembly
- 4 Main Assembly

B2 Cooling Fan Subassembly

- 1 Fan Bracket
- 2 Fan Screws
- 3 Fan PCB
- 4 Cooling Fan

B3 Cover Subassembly

- 1 Face Plate
- 2 A-Drive Covers
- 3 Steel Mesh Pad
- 4 Cover Base

B4 Drive Bracket Subassembly

- 1 C-Drive Controller
- 2 Drive Bracket
- 3 C-Drive
- 4 System Speaker/Clock Battery
- 5 A-Drive
- 6 A-Drive Controller
- 7 A-Drive Controlled Lock-Down

B5 Main Assembly

- 1 Power Supply
- 2 Base
- 3 Mother Board

Appendix C

GM C/K Truck Dashboard Assembly Drawings

- C1 Knee Bolster and Instrument Cluster**
- C2 Storage Compartment and Bezel Cluster Trim**
- C3 Ashtray and Cupholder**
- C4 HVAC Control**
- C5 Dash, Rear View**
- C6 Duct**
- C7 Wire Harness**

C1 Knee Bolster and Instrument Cluster

Figure 3—Knee Bolster

Figure 13—Instrument Cluster

C2 Storage Compartment and Bezel Cluster Trim

Figure 12—I/P Storage Compartment

Figure 8—Instrument Cluster Trim

C3 Ashtray and Cupholder

Figure 10—Ashtray

Figure 11—Cupholder

C5 Dash, Rear View

C7 Wire Harness

Appendix D

IBM PS/2 DFDE SHEETS

- D1 IBM PS/2 Personal Computer Arbitrary Sequence DFDE Sheets**
- D2 IBM PS/2 Personal Computer Optimized Sequence DFDE Sheets**

Eco \$ Factor:	1.00
Labor Rate:	30.00
Regular LF rate, \$/kg	0.04
Special LF Rate, \$/kg	0.07
Regular Incin Rate, \$/kg	0.05
Special incin Rate, \$/kg	0.09

Rest	c	N
Default:	f	\$

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	IBM PS2	1.0	-	1.00	0.0	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Screw Unfasten	1.1	-	2.00	20.2	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Cover ssy	1.2/2	1.1	1.00	4.2	1.231	0	0	0	c	y	0.312	0.030	0.048	0.124	0.067	0.010	0.089	0.558
4	Cover Thumb Scrs	1.3	1.1	2.00	6.4	0.013	2	10	1.6E-7	b	y	0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.002
5	-	-	-	-	0.0	0.003	16	5	0.004	b	y	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
6	Slot Covers	1.4	1.2	3.00	21.9	0.013	1	10	4.9E-6	b	y	0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.002
7	Drive Bracket ssy	1.6/3	1.2	1.00	12.0	3.328	0	0	0	d	y	3.950	0.081	0.183	0.622	1.007	0.062	0.387	3.960
8	Power Sup Screws	1.7	1.2	3.00	21.3	0.012	2	10	2E-04	b	y	0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.001
9	Power Supply	1.8	1.7	1.00	4.2	0.800	1	3	0.232	2.00	y	0.070	0.212	0.034	0.100	0.040	0.008	0.058	0.096
10	-	-	-	-	0.0	0.333	9	9	0.127	0.00	y	0.387	0.008	0.007	0.001	0.024	0.000	0.024	0.517
11	-	-	-	-	0.0	0.333	29	5	0.356	0.00	y	0.633	0.016	0.033	0.267	0.350	0.027	0.090	0.200
12	Mthr Brd Bck Scrs	1.9	-	3.00	21.3	0.005	2	10	5E-05	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
13	Mthr Brd Btm Scrs	1.10	1.6	3.00	21.3	0.005	2	10	5E-05	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
14	Mother Board	1.11	(1.10-8)	1.00	3.9	0.978	29	9	0.102	b		1.858	0.007	0.098	0.782	1.027	0.078	0.265	0.587
15	Slot Cover Holder	1.12	1.11	1.00	5.6	0.030	1	10	1.6E-6	b		0.003	0.000	0.001	0.004	0.002	0.000	0.002	0.004
16	Plastic Brcket	1.13	1.2	1.00	3.2	0.002	9	5	0.003	b		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003
17	Nut	1.14	1.2	1.00	13.6	0.002	2	10	1.6E-7	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	Star Washer	1.15	1.14	1.00	3.8	0.002	1	10	1.6E-6	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	Locking Bracket	1.16	1.15	1.00	3.8	0.020	1	10	1.6E-6	b		0.002	0.000	0.001	0.002	0.001	0.000	0.001	0.002
20	Lock Retainer Clip	1.17	1.2	1.00	7.8	0.002	1	10	1.6E-6	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	Lock	1.18	1.17	1.00	3.8	0.034	2	10	1.6E-6	0.50		0.004	0.000	0.001	0.004	0.002	0.000	0.002	0.004
22	Lock Position Ring	1.19	1.18	1.00	3.8	0.001	16	5	0.002	b		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
23	Bottom Sticker	1.20	-	1.00	5.0	0.001	16	5	0.001	c		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
24	Back Stickers	1.21	-	3.00	15.0	0.003	16	5	0.003	c		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
25	Steel Wool Inserts	1.22	1.11	6.00	34.8	0.005	1	7	0.006	c		0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
26	Threaded Inserts	1.23	1.11	4.00	41.4	0.020	2	10	6.5E-6	c		0.002	0.000	0.001	0.002	0.001	0.000	0.001	0.002
27	Rubber Feet	1.24	-	4.00	20.0	0.016	23	5	0.016	c		0.002	0.001	0.000	0.000	0.001	0.000	0.001	0.000
28	Base	1.25	1.24-1	1.00	3.8	0.782	16	5	0.844	b		0.720	0.037	0.017	0.003	0.056	0.000	0.056	1.408
29	-	-	-	-	0.0	0.000	0	1	0.361	b		0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	IBM PS2	1.0	-9.3467	-0.71771	0	0	0.0	-0.72	-9.34670	-10.06	-10.06
2	Screw Unfasten	1.1	-9.3467	-0.71771	-0.17	0	20.2	-0.89	-9.34670	-10.23	-0.17
3	Cover ssy	1.2/2	-8.91616	-0.60691	-0.08	-0.46621	24.4	-0.86	-9.38237	-10.24	-0.01
4	Cover Thumb Scrs	1.3	-8.91382	-0.60571	-0.05	-0.00057	30.8	-0.91	-9.38061	-10.29	-0.05
5	-	-	-8.91098	-0.60547	0	-0.00025	30.8	-0.90	-9.37802	-10.28	0.01
6	Slot Covers	1.4	-8.90885	-0.60427	-0.18	-0.00057	52.7	-1.08	-9.37646	-10.46	-0.18
7	Drive Bracket ssy	1.6/3	-4.49115	-0.30472	-0.33	-4.0927	64.7	-1.12	-9.05146	-10.17	0.29
8	Power Sup Screws	1.7	-4.48904	-0.30364	-0.18	-0.00052	86.0	-1.29	-9.04987	-10.34	-0.17
9	Power Supply	1.8	-4.14876	-0.23164	1.97	0	90.2	0.74	-8.70959	-7.97	2.38
10	-	-	-3.72984	-0.20164	0	0	90.2	0.77	-8.29067	-7.52	0.45
11	-	-	-2.99053	-0.17164	0	0	90.2	0.80	-7.55136	-6.75	0.77
12	Mthr Brd Bck Scrs	1.9	-2.98959	-0.17116	-0.18	-0.00023	111.5	0.63	-7.55066	-6.92	-0.18
13	Mthr Brd Btm Scrs	1.10	-2.98866	-0.17068	-0.18	-0.00023	132.8	0.45	-7.54995	-7.10	-0.18
14	Mother Board	1.11	-0.81065	-0.03675	0.55	-0.10438	136.7	1.14	-5.47633	-4.34	2.76
15	Slot Cover Holder	1.12	-0.80421	-0.03554	-0.04	-0.0013	142.3	1.10	-5.47119	-4.37	-0.04
16	Plastic Brcket	1.13	-0.80201	-0.03547	-0.02	-0.00018	145.5	1.07	-5.46916	-4.40	-0.02
17	Nut	1.14	-0.8016	-0.0354	-0.11	-7.6E-05	159.1	0.96	-5.46883	-4.51	-0.11
18	Star Washer	1.15	-0.80122	-0.03532	-0.03	-7.7E-05	162.9	0.93	-5.46853	-4.54	-0.03
19	Locking Bracket	1.16	-0.79706	-0.03454	-0.03	-0.00084	166.7	0.90	-5.46520	-4.56	-0.03
20	Lock Retainer Clip	1.17	-0.79668	-0.03447	-0.06	-7.7E-05	174.5	0.84	-5.46490	-4.63	-0.06
21	Lock	1.18	-0.78888	-0.0331	0.47	0	178.3	1.31	-5.45710	-4.15	0.48
22	Lock Position Ring	1.19	-0.78797	-0.03307	-0.03	-0.00011	182.1	1.28	-5.45630	-4.18	-0.03
23	Bottom Sticker	1.20	-0.7871	-0.03303	-0.04	-0.00087	187.1	1.23	-5.45630	-4.22	-0.04
24	Back Stickers	1.21	-0.7845	-0.03292	-0.13	-0.0026	202.1	1.11	-5.45630	-4.35	-0.12
25	Steel Wool Inserts	1.22	-0.78316	-0.03271	-0.29	-0.00135	236.9	0.82	-5.45630	-4.64	-0.29
26	Threaded Inserts	1.23	-0.7787	-0.03193	-0.35	-0.00446	278.3	0.47	-5.45630	-4.98	-0.35
27	Rubber Feet	1.24	-0.77617	-0.03129	-0.17	-0.00253	298.3	0.31	-5.45630	-5.15	-0.17
28	Base	1.25	-0.01625	0	1.38	-0.05436	302.1	1.71	-4.75073	-3.04	2.11
29	-	-	0	0	0	-0.01625	302.1	1.71	-4.75073	-3.04	0.00

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Cover ssy	1.2/2	1.1	1.00	0.0	0.000	0	0	0	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Stickers	2.1	-	2.00	10.0	0.002	16	5	0.001	c		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003
3	A-Drive Covers	2.2	1.2	2.00	13.4	0.055	16	5	0.033	b		0.051	0.001	0.001	0.000	0.004	0.000	0.004	0.099
4	Face Plate	2.3	2.1,2.2	1.00	8.8	0.188	16	5	0.196	b		0.173	0.009	0.004	0.001	0.013	0.000	0.014	0.338
5	-	-	-	-	0.0	0.000	0	1	0.036	b		0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
6	Steel Mesh Pads	2.4	1.2	5.00	25.0	0.009	2	7	0.009	b		0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.001
7	Cover Base	2.5	2.4,2.3	1.00	3.8	0.978	1	1	0.4	b		0.086	0.018	0.042	0.122	0.049	0.010	0.070	0.117

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Drive Bracket ssy	1.6/3	1.2	1.00	0.0	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Sys Spkr/Click Btry	3.1	1.6	1.00	8.8	0.022	16	10	1.6E-6	1.00	y	0.020	0.000	0.000	0.000	0.002	0.000	0.002	0.040
3	-	-	-	-	0.0	0.071	2	5	0.033	0.00	y	0.007	0.001	0.003	0.009	0.004	0.001	0.005	0.009
4	-	-	-	-	0.0	0.012	29	0	0	0.00	y	0.024	0.000	0.001	0.010	0.013	0.001	0.003	0.007
5	A-Drive	3.2	1.2	1.00	8.8	0.622	4	9	0.076	5.00	y	0.641	0.005	0.037	0.006	0.065	0.001	0.045	0.653
6	-	-	-	-	0.0	0.178	16	5	0.267	0.00	y	0.164	0.012	0.004	0.001	0.013	0.000	0.013	0.320
7	-	-	-	-	0.0	0.178	29	10	0.016	0.00	y	0.338	0.001	0.018	0.142	0.187	0.014	0.048	0.107
8	A-Drive Cntrlr Lock	3.3	1.2	1.00	3.2	0.001	2	7	0.001	b	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	A-Drive Controller	3.4	3.3	1.00	3.8	0.063	29	9	0.025	b	y	0.119	0.002	0.006	0.050	0.066	0.005	0.017	0.038
10	C-Drive	3.5	1.2	1.00	8.8	0.711	4	9	0.025	15.00	y	0.732	0.002	0.043	0.007	0.075	0.001	0.051	0.747
11	-	-	-	-	0.0	0.231	16	5	0.127	0.00	y	0.213	0.006	0.005	0.001	0.016	0.000	0.017	0.416
12	-	-	-	-	0.0	0.231	29	10	0.033	0.00	y	0.439	0.001	0.023	0.185	0.243	0.018	0.063	0.139
13	C-Drive Controller	3.6	3.5	1.00	3.2	0.227	29	10	0.102	b	y	0.431	0.004	0.023	0.182	0.238	0.018	0.062	0.136
14	Locking Pins	3.7	1.6	7.00	36.4	0.022	16	5	0.028	b	y	0.020	0.001	0.000	0.000	0.002	0.000	0.002	0.039
15	Locking Pin Capture	3.8	3.7	7.00	22.4	0.022	16	5	0.028	b	y	0.020	0.001	0.000	0.000	0.002	0.000	0.002	0.039
16	Cooling Fan ssy	3.9/4	1.2	1.00	3.2	0.195	0	0	0	d	y	0.283	0.020	0.006	0.027	0.045	0.003	0.019	0.293
17	Drive Bracket	3.10	3.9-1	1.00	3.8	0.543	16	5	0.6	e		0.499	0.026	0.012	0.002	0.039	0.000	0.039	0.977

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Cooling Fan ssy	3.9/4	1.2	1.00	0.0	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Warning Label	4.1	1.2	1.00	5.0	0.001	16	5	0.001	c	y	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
3	Locking Pin	4.2	1.2	2.00	13.4	0.004	16	5	0.005	b	y	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.006
4	Locking Pin Capture	4.3	4.2	2.00	6.4	0.006	16	5	0.008	b	y	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.011
5	Fan Board	4.4	1.5	1.00	5.3	0.005	29	9	0.01	c	y	0.009	0.001	0.000	0.004	0.005	0.000	0.001	0.003
6	Fan Screws	4.5	1.5	2.00	19.2	0.008	2	10	1.6E-6	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.001
7	Fan	4.6	4.5, 4.4	1.00	3.8	0.067	9	5	0.076	1.00	y	0.077	0.003	0.001	0.000	0.005	0.000	0.005	0.103
8	-	-	-	-	0.0	0.016	29	7	0.044	0.00	y	0.030	0.002	0.002	0.013	0.017	0.001	0.004	0.010
9	-	-	-	-	0.0	0.044	5	9	0.02	0.00	y	0.114	0.001	0.001	0.009	0.014	0.001	0.004	0.078
10	Fan Bracket	4.7	4.6-1	1.00	3.8	0.044	16	5	0.049	b		0.040	0.002	0.001	0.000	0.003	0.000	0.003	0.079
11	-	-	-	-	0.0	0.000	0	1	0.226	e		0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Cover ssy	1.2/2	-0.46621	-0.04924	0	0	0.0	-0.05	-0.46621	-0.52	-0.52
2	Stickers	2.1	-0.46452	-0.04917	-0.08	-0.00189	10.0	-0.13	-0.46621	-0.60	-0.08
3	A-Drive Covers	2.2	-0.41213	-0.04697	-0.01	-0.00288	23.4	-0.14	-0.41650	-0.56	0.04
4	Face Plate	2.3	-0.23023	-0.03947	0.26	-0.01273	32.2	0.13	-0.24732	-0.12	0.44
5	-	-	-0.2286	-0.03947	0	-0.00162	32.2	0.13	-0.24732	-0.12	0.00
6	Steel Mesh Pads	2.4	-0.22627	-0.03911	-0.21	-0.00069	57.2	-0.08	-0.24568	-0.32	-0.21
7	Cover Base	2.5	0	0	0.09	-0.06004	61.0	0.05	-0.07946	-0.03	0.29

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Drive Bracket ssy	1.6/3	-4.4177	-0.29955	0	0	0.0	-0.30	-4.41770	-4.72	-4.72
2	Sys Spkr/Click Btry	3.1	-4.39566	-0.29755	0.93	0	8.8	0.63	-4.39566	-3.77	0.95
3	-	-	-4.38175	-0.29115	0	0	8.8	0.64	-4.38175	-3.75	0.02
4	-	-	-4.35473	-0.29003	0	0	8.8	0.64	-4.35473	-3.72	0.03
5	A-Drive	3.2	-3.66434	-0.23405	4.93	0	17.6	5.62	-3.66434	1.95	5.67
6	-	-	-3.47603	-0.21803	0	0	17.6	5.64	-3.47603	2.16	0.20
7	-	-	-3.0895	-0.20203	0	0	17.6	5.65	-3.08950	2.56	0.40
8	A-Drive Cntrlr Lock	3.3	-3.08931	-0.20195	-0.03	-7.3E-05	20.8	5.62	-3.08938	2.54	-0.03
9	A-Drive Controller	3.4	-2.95161	-0.19631	0.01	-0.00792	24.6	5.64	-2.95960	2.68	0.14
10	C-Drive	3.5	-2.16634	-0.13231	14.9	0	33.4	20.63	-2.17433	18.45	15.78
11	-	-	-1.93149	-0.11151	0	0	33.4	20.65	-1.93948	18.71	0.26
12	-	-	-1.4286	-0.09071	0	0	33.4	20.67	-1.43659	19.23	0.52
13	C-Drive Controller	3.6	-0.93222	-0.07028	0.11	-0.02626	36.6	20.80	-0.96647	19.83	0.60
14	Locking Pins	3.7	-0.90939	-0.06832	-0.26	-0.00171	73.0	20.54	-0.94535	19.59	-0.24
15	Locking Pin Capture	3.8	-0.88655	-0.06636	-0.15	-0.00171	95.4	20.39	-0.92422	19.47	-0.12
16	Cooling Fan ssy	3.9/4	-0.56473	-0.04884	-0.04	-0.30501	98.6	20.37	-0.90740	19.46	-0.01
17	Drive Bracket	3.10	0	0	-0.06	-0.56418	102.4	20.36	-0.90686	19.45	-0.01

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Cooling Fan ssy	3.9/4	-0.32183	-0.01752	0	0	0.0	-0.02	-0.32183	-0.34	-0.34
2	Warning Label	4.1	-0.3209	-0.01744	-0.04	-0.00087	5.0	-0.06	-0.32177	-0.38	-0.04
3	Locking Pin	4.2	-0.31714	-0.01712	-0.11	-0.00031	18.4	-0.16	-0.31832	-0.48	-0.10
4	Locking Pin Capture	4.3	-0.31061	-0.01656	-0.04	-0.00049	24.8	-0.21	-0.31228	-0.52	-0.04
5	Fan Board	4.4	-0.29935	-0.01612	-0.04	-0.01385	30.1	-0.25	-0.31487	-0.56	-0.05
6	Fan Screws	4.5	-0.29795	-0.0154	-0.16	-0.00034	49.3	-0.41	-0.31381	-0.72	-0.16
7	Fan	4.6	-0.21249	-0.0094	0.97	0	53.1	0.57	-0.22835	0.34	1.06
8	-	-	-0.1762	-0.00796	0	0	53.1	0.57	-0.19206	0.38	0.04
9	-	-	-0.05597	-0.00396	0	0	53.1	0.57	-0.07183	0.50	0.12
10	Fan Bracket	4.7	-0.01017	0	0.05	-0.00312	56.9	0.62	-0.02915	0.59	0.09
11	-	-	0	0	0	-0.01017	56.9	0.62	-0.02915	0.59	0.00

Eco \$ Factor:	1.00
Labor Rate:	30.00
Regular LF rate, \$/kg	0.04
Special LF Rate, \$/kg	0.07
Regular Incin Rate, \$/kg	0.05
Special incin Rate, \$/kg	0.09

Rest	c	N
Default:	f	S

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	IBM PS2	1.0	-	1.00	0.0	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Screw Unfasten	1.1	-	2.00	20.2	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Cover ssy	1.2/2	1.1	1.00	4.2	1.231	0	0	0	c	y	0.312	0.030	0.048	0.124	0.067	0.010	0.089	0.558
10	C-Drive	3.5	1.2	1.00	8.8	0.711	4	9	0.025	15.00	y	0.732	0.002	0.043	0.007	0.075	0.001	0.051	0.747
11	-	-	-	-	0.0	0.231	16	5	0.127	0.00	y	0.213	0.006	0.005	0.001	0.016	0.000	0.017	0.416
12	-	-	-	-	0.0	0.231	29	10	0.033	0.00	y	0.439	0.001	0.023	0.185	0.243	0.018	0.063	0.139
5	A-Drive	3.2	1.2	1.00	8.8	0.622	4	9	0.076	5.00	y	0.641	0.005	0.037	0.006	0.065	0.001	0.045	0.653
6	-	-	-	-	0.0	0.178	16	5	0.267	0.00	y	0.164	0.012	0.004	0.001	0.013	0.000	0.013	0.320
7	-	-	-	-	0.0	0.178	29	10	0.016	0.00	y	0.338	0.001	0.018	0.142	0.187	0.014	0.048	0.107
13	C-Drive Controller	3.6	3.5	1.00	3.2	0.227	29	10	0.102	b	y	0.431	0.004	0.023	0.182	0.238	0.018	0.062	0.136
8	Power Sup Screws	1.7	1.2	3.00	21.3	0.012	2	10	2E-04	b	y	0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.001
9	Power Supply	1.8	1.7	1.00	4.2	0.800	1	3	0.232	2.00	y	0.070	0.212	0.034	0.100	0.040	0.008	0.058	0.096
10	-	-	-	-	0.0	0.333	9	9	0.127	0.00	y	0.387	0.008	0.007	0.001	0.024	0.000	0.024	0.517
11	-	-	-	-	0.0	0.333	29	5	0.358	0.00	y	0.633	0.016	0.033	0.267	0.350	0.027	0.090	0.200
7	Drive Bracket ssy	1.6/3	1.2	1.00	12.0	0.950	0	0	0	d	y	0.992	0.052	0.030	0.099	0.170	0.009	0.089	1.442
12	Mthr Brd Bck Scrs	1.9	-	3.00	21.3	0.005	2	10	5E-05	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
13	Mthr Brd Btm Scrs	1.10	1.6	3.00	21.3	0.005	2	10	5E-05	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
14	Mother Board	1.11	(1.10-8)	1.00	3.9	0.978	29	9	0.102	b		1.858	0.007	0.098	0.782	1.027	0.078	0.265	0.587
17	Nut	1.14	1.2	1.00	13.6	0.002	2	10	1.6E-7	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	Star Washer	1.15	1.14	1.00	3.8	0.002	1	10	1.6E-6	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	Locking Bracket	1.16	1.15	1.00	3.8	0.020	1	10	1.6E-6	b		0.002	0.000	0.001	0.002	0.001	0.000	0.001	0.002
20	Lock Retainer Clip	1.17	1.2	1.00	7.8	0.002	1	10	1.6E-6	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	Lock	1.18	1.17	1.00	3.8	0.034	2	10	1.6E-6	0.50		0.004	0.000	0.001	0.004	0.002	0.000	0.002	0.004
4	Cover Thumb Scrs	1.3	1.1	2.00	6.4	0.013	2	10	1.6E-7	b		0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.002
5	-	-	-	-	0.0	0.003	16	5	0.004	b		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
6	Slot Covers	1.4	1.2	3.00	21.9	0.013	1	10	4.9E-6	b		0.001	0.000	0.001	0.002	0.001	0.000	0.001	0.002
15	Slot Cover Holder	1.12	1.11	1.00	5.6	0.030	1	10	1.6E-6	b		0.003	0.000	0.001	0.004	0.002	0.000	0.002	0.004
16	Plastic Brcket	1.13	1.2	1.00	3.2	0.002	9	5	0.003	b		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003
22	Lock Position Ring	1.19	1.18	1.00	3.8	0.001	16	5	0.002	b		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
23	Bottom Sticker	1.20	-	1.00	5.0	0.001	16	5	0.001	c		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
24	Back Stickers	1.21	-	3.00	15.0	0.003	16	5	0.003	c		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
25	Steel Wool Inserts	1.22	1.11	6.00	34.8	0.005	1	7	0.006	c		0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
26	Threaded Inserts	1.23	1.11	4.00	41.4	0.020	2	10	6.5E-6	c		0.002	0.000	0.001	0.002	0.001	0.000	0.001	0.002
27	Rubber Feet	1.24	-	4.00	20.0	0.016	23	5	0.016	c		0.002	0.001	0.000	0.000	0.001	0.000	0.001	0.000
28	Base	1.25	1.24-1	1.00	3.8	0.782	16	5	0.844	b		0.720	0.037	0.017	0.003	0.056	0.000	0.056	1.408
29	-	-	-	-	0.0	0.000	0	1	0.361	b		0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	IBM PS2	1.0	-9.3467	-0.71771	0	0	0.0	-0.72	-9.34670	-10.06	-10.06
2	Screw Unfasten	1.1	-9.3467	-0.71771	-0.17	0	20.2	-0.89	-9.34670	-10.23	-0.17
3	Cover ssy	1.2/2	-8.91616	-0.60691	-0.08	-0.46621	24.4	-0.86	-9.38237	-10.24	-0.01
10	C-Drive	3.5	-8.13089	-0.54291	14.9	0	33.2	14.13	-8.59710	5.53	15.78
11	-	-	-7.89604	-0.52211	0	0	33.2	14.15	-8.36225	5.79	0.26
12	-	-	-7.39315	-0.50131	0	0	33.2	14.17	-7.85936	6.31	0.52
5	A-Drive	3.2	-6.70275	-0.44533	4.93	0	42.0	19.16	-7.16896	11.99	5.67
6	-	-	-6.51444	-0.42931	0	0	42.0	19.17	-6.98065	12.19	0.20
7	-	-	-6.12791	-0.41331	0	0	42.0	19.19	-6.59412	12.59	0.40
13	C-Drive Controller	3.6	-5.63154	-0.39288	0.11	-0.02626	45.2	19.32	-6.12401	13.19	0.60
8	Power Sup Screws	1.7	-5.62943	-0.3918	-0.18	-0.00052	66.5	19.14	-6.12242	13.02	-0.17
9	Power Supply	1.8	-5.28915	-0.3198	1.97	0	70.7	21.18	-5.78214	15.40	2.38
10	-	-	-4.87023	-0.2898	0	0	70.7	21.21	-5.36322	15.85	0.45
11	-	-	-4.13092	-0.2598	0	0	70.7	21.24	-4.62391	16.62	0.77
7	Drive Bracket ssy	1.6/3	-2.99784	-0.17428	-0.17	-1.05365	82.7	21.16	-4.54447	16.61	0.00
12	Mthr Brd Bck Scrs	1.9	-2.9969	-0.1738	-0.18	-0.00023	104.0	20.98	-4.54376	16.44	-0.18
13	Mthr Brd Btm Scrs	1.10	-2.99597	-0.17332	-0.18	-0.00023	125.3	20.81	-4.54306	16.26	-0.18
14	Mother Board	1.11	-0.81919	-0.03792	0.55	-0.10438	129.2	21.50	-2.47067	19.02	2.76
17	Nut	1.14	-0.81878	-0.03785	-0.11	-7.6E-05	142.8	21.38	-2.47034	18.91	-0.11
18	Star Washer	1.15	-0.81841	-0.03778	-0.03	-7.7E-05	146.6	21.35	-2.47004	18.88	-0.03
19	Locking Bracket	1.16	-0.81424	-0.037	-0.03	-0.00084	150.4	21.32	-2.46671	18.86	-0.03
20	Lock Retainer Clip	1.17	-0.81386	-0.03692	-0.06	-7.7E-05	158.2	21.26	-2.46641	18.79	-0.06
21	Lock	1.18	-0.80606	-0.03556	0.47	0	162.0	21.73	-2.45861	19.27	0.48
4	Cover Thumb Scrs	1.3	-0.80302	-0.03502	-0.05	-0.00057	168.4	21.68	-2.45614	19.22	-0.05
5	-	-	-0.80036	-0.03492	0	-0.00025	168.4	21.68	-2.45373	19.23	0.01
6	Slot Covers	1.4	-0.79752	-0.03438	-0.18	-0.00057	190.3	21.50	-2.45147	19.05	-0.18
15	Slot Cover Holder	1.12	-0.79108	-0.03317	-0.04	-0.0013	195.9	21.46	-2.44633	19.01	-0.04
16	Plastic Brcket	1.13	-0.78888	-0.0331	-0.02	-0.00018	199.1	21.43	-2.44430	18.99	-0.02
22	Lock Position Ring	1.19	-0.78797	-0.03307	-0.03	-0.00011	202.9	21.40	-2.44350	18.96	-0.03
23	Bottom Sticker	1.20	-0.7871	-0.03303	-0.04	-0.00087	207.9	21.36	-2.44350	18.92	-0.04
24	Back Stickers	1.21	-0.7845	-0.03292	-0.13	-0.0026	222.9	21.24	-2.44350	18.79	-0.13
25	Steel Wool Inserts	1.22	-0.78316	-0.03271	-0.29	-0.00135	257.7	20.95	-2.44350	18.50	-0.29
26	Threaded Inserts	1.23	-0.7787	-0.03193	-0.35	-0.00446	299.1	20.60	-2.44350	18.16	-0.34
27	Rubber Feet	1.24	-0.77617	-0.03129	-0.17	-0.00253	319.1	20.44	-2.44350	17.99	-0.17
28	Base	1.25	-0.01625	0	1.38	-0.05436	322.9	21.84	-1.73793	20.11	2.11
29	-	-	0	0	0	-0.01625	322.9	21.84	-1.73793	20.11	0.00

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Cover ssy	1.2/2	1.1	1.00	0.0	0.000	0	0	0	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Stickers	2.1	-	2.00	10.0	0.002	16	5	0.001	c		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003
3	A-Drive Covers	2.2	1.2	2.00	13.4	0.055	16	5	0.033	b		0.051	0.001	0.001	0.000	0.004	0.000	0.004	0.099
4	Face Plate	2.3	2.1,2.2	1.00	8.8	0.188	16	5	0.196	b		0.173	0.009	0.004	0.001	0.013	0.000	0.014	0.338
5	-	-	-	-	0.0	0.000	0	1	0.036	b		0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
6	Steel Mesh Pads	2.4	1.2	5.00	25.0	0.009	2	7	0.009	b		0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.001
7	Cover Base	2.5	2.4,2.3	1.00	3.8	0.978	1	1	0.4	b		0.086	0.018	0.042	0.122	0.049	0.010	0.070	0.117

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Drive Bracket ssy	1.6/3	1.2	1.00	0.0	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Sys Spkr/Click Btry	3.1	1.6	1.00	8.8	0.022	16	10	1.6E-6	1.00	y	0.020	0.000	0.000	0.000	0.002	0.000	0.002	0.040
3	-	-	-	-	0.0	0.071	2	5	0.033	0.00	y	0.007	0.001	0.003	0.009	0.004	0.001	0.005	0.009
4	-	-	-	-	0.0	0.012	29	0	0	0.00	y	0.024	0.000	0.001	0.010	0.013	0.001	0.003	0.007
16	Cooling Fan ssy	3.9/4	1.2	1.00	3.2	0.195	0	0	0	d	y	0.283	0.020	0.006	0.027	0.045	0.003	0.019	0.293
8	A-Drive Cntrlr Lock	3.3	1.2	1.00	3.2	0.001	2	7	0.001	b	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	A-Drive Controller	3.4	3.3	1.00	3.8	0.063	29	9	0.025	b		0.119	0.002	0.006	0.050	0.066	0.005	0.017	0.038
14	Locking Pins	3.7	1.6	7.00	36.4	0.022	16	5	0.028	b		0.020	0.001	0.000	0.000	0.002	0.000	0.002	0.039
15	Locking Pin Capture	3.8	3.7	7.00	22.4	0.022	16	5	0.028	b		0.020	0.001	0.000	0.000	0.002	0.000	0.002	0.039
17	Drive Bracket	3.10	3.9-1	1.00	3.8	0.543	16	5	0.6	c		0.499	0.026	0.012	0.002	0.039	0.000	0.039	0.977

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Cooling Fan ssy	3.9/4	1.2	1.00	0.0	0.000	0	0	0	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Fan Board	4.4	1.5	1.00	5.3	0.005	29	9	0.01	c		0.009	0.001	0.000	0.004	0.005	0.000	0.001	0.003
6	Fan Screws	4.5	1.5	2.00	19.2	0.008	2	10	1.6E-6	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.001
7	Fan	4.6	4.5, 4.4	1.00	3.8	0.067	9	5	0.076	1.00		0.077	0.003	0.001	0.000	0.005	0.000	0.005	0.103
8	-	-	-	-	0.0	0.016	29	7	0.044	0.00		0.030	0.002	0.002	0.013	0.017	0.001	0.004	0.010
9	-	-	-	-	0.0	0.044	5	9	0.02	0.00		0.114	0.001	0.001	0.009	0.014	0.001	0.004	0.078
2	Warning Label	4.1	1.2	1.00	5.0	0.001	16	5	0.001	c		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
3	Locking Pin	4.2	1.2	2.00	13.4	0.004	16	5	0.005	b		0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.006
4	Locking Pin Capture	4.3	4.2	2.00	6.4	0.006	16	5	0.008	b		0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.011
10	Fan Bracket	4.7	4.6-1	1.00	3.8	0.044	16	5	0.049	b		0.040	0.002	0.001	0.000	0.003	0.000	0.003	0.079
11	-	-	-	-	0.0	0.000	0	1	0.226	b		0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Cover ssy	1.2/2	-0.46621	-0.04924	0	0	0.0	-0.05	-0.46621	-0.52	-0.52
2	Stickers	2.1	-0.46452	-0.04917	-0.08	-0.00169	10.0	-0.13	-0.46621	-0.60	-0.08
3	A-Drive Covers	2.2	-0.41213	-0.04697	-0.01	-0.00268	23.4	-0.14	-0.41650	-0.56	0.04
4	Face Plate	2.3	-0.23023	-0.03947	0.26	-0.01273	32.2	0.13	-0.24732	-0.12	0.44
5	-	-	-0.2286	-0.03947	0	-0.00162	32.2	0.13	-0.24732	-0.12	0.00
6	Steel Mesh Pads	2.4	-0.22627	-0.03911	-0.21	-0.00069	57.2	-0.08	-0.24568	-0.32	-0.21
7	Cover Base	2.5	0	0	0.09	-0.06004	61.0	0.05	-0.07946	-0.03	0.29

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Drive Bracket ssy	1.6/3	-1.13309	-0.08552	0	0	0.0	-0.09	-1.13309	-1.22	-1.22
2	Sys Spkr/Click Btry	3.1	-1.11104	-0.08352	0.93	0	8.8	0.84	-1.11104	-0.27	0.95
3	-	-	-1.09713	-0.07712	0	0	8.8	0.85	-1.09713	-0.25	0.02
4	-	-	-1.07011	-0.076	0	0	8.8	0.85	-1.07011	-0.22	0.03
16	Cooling Fan ssy	3.9/4	-0.74829	-0.05848	-0.04	-0.30501	12.0	0.83	-1.05329	-0.23	-0.01
8	A-Drive Cntrlr Lock	3.3	-0.7481	-0.0584	-0.03	-7.3E-05	15.2	0.80	-1.05318	-0.25	-0.03
9	A-Drive Controller	3.4	-0.57053	-0.02345	0.01	-0.00792	19.0	0.84	-0.88353	-0.04	0.21
14	Locking Pins	3.7	-0.54918	-0.02258	-0.26	-0.00171	55.4	0.58	-0.86389	-0.28	-0.24
15	Locking Pin Capture	3.8	-0.52782	-0.02171	-0.15	-0.00171	77.8	0.43	-0.84424	-0.41	-0.13
17	Drive Bracket	3.10	0	0	-0.05	-0.52782	81.6	0.40	-0.84424	-0.44	-0.03

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Cooling Fan ssy	3.9/4	-0.32183	-0.01752	0	0	0.0	-0.02	-0.32183	-0.34	-0.34
5	Fan Board	4.4	-0.31056	-0.01708	-0.04	-0.01385	5.3	-0.06	-0.32441	-0.39	-0.05
6	Fan Screws	4.5	-0.30916	-0.01636	-0.16	-0.00034	24.5	-0.22	-0.32336	-0.54	-0.16
7	Fan	4.6	-0.23285	-0.0046	0.97	0	28.3	0.76	-0.24705	0.51	1.06
8	-	-	-0.1881	-0.00396	0	0	28.3	0.76	-0.20229	0.56	0.05
9	-	-	-0.06346	-0.00219	0	0	28.3	0.76	-0.07766	0.69	0.13
2	Warning Label	4.1	-0.0626	-0.00215	-0.04	-0.00087	33.3	0.72	-0.07766	0.64	-0.04
3	Locking Pin	4.2	-0.05908	-0.00201	-0.11	-0.00031	46.7	0.62	-0.07445	0.54	-0.10
4	Locking Pin Capture	4.3	-0.05298	-0.00176	-0.04	-0.00049	53.1	0.57	-0.06884	0.51	-0.04
10	Fan Bracket	4.7	-0.01017	0	0.05	-0.00312	56.9	0.62	-0.02915	0.59	0.09
11	-	-	0	0	0	-0.01017	56.9	0.62	-0.02915	0.59	0.00

Appendix E

GM C/K Truck Dashboard DFDE Sheets

E1 GM C/K Truck Dashboard Optimized Sequence DFDE Sheets

Eco \$ Factor:	3.00
Labor Rate:	30.00
Regular LF rate, \$/kg	0.04
Special LF Rate, \$/kg	0.07
Regular Incin Rate, \$/kg	0.05
Special incin Rate, \$/kg	0.09

Rest	c	N
Default:	d	S

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	GM C/K Truck Dash	1.0	-	1.00	0.0	0.0000	0	0	0.000	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	-	-	-	1.00	0.0	0.0000	0	0	0.000	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	Inst Plate Bezel ssy	1.14/10	-	1.00	29.5	1.5356	0	0	0.000	c	y	1.260	0.076	0.034	0.008	0.109	0.000	0.111	2.254
40	screws (clust ssy)	1.32	1.14	4.00	27.0	0.0053	2	10	0.001	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
41	Instrument Cluster	1.33	1.32	1.00	5.4	0.0044	1	5	1.082	200	y	0.000	0.048	0.000	0.001	0.000	0.000	0.000	0.001
42	-	-	-	0.00	0.0	0.0333	2	7	0.081	0	y	0.003	0.003	0.001	0.004	0.002	0.000	0.002	0.004
43	-	-	-	0.00	0.0	0.0942	5	9	0.025	0	y	0.243	0.002	0.003	0.019	0.029	0.002	0.010	0.165
44	-	-	-	0.00	0.0	0.7796	9	10	0.006	0	y	0.904	0.000	0.017	0.003	0.055	0.000	0.056	1.208
45	-	-	-	0.00	0.0	0.1791	16	0	0.000	0	y	0.165	0.000	0.004	0.001	0.013	0.000	0.013	0.322
46	-	-	-	0.00	0.0	0.0067	23	0	0.000	0	y	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	-	-	-	0.00	0.0	0.0213	25	0	0.000	0	y	0.003	0.000	0.001	0.000	0.000	0.000	0.002	0.001
48	-	-	-	0.00	0.0	0.0449	29	0	0.000	0	y	0.085	0.000	0.004	0.036	0.047	0.004	0.012	0.027
17	Temp Ctrl/HVAC	1.17	1.14	3.00	16.7	0.0102	5	5	0.327	135	y	0.026	0.014	0.000	0.002	0.003	0.000	0.001	0.018
18	-	-	-	0.00	0.0	0.0142	9	7	0.010	0	y	0.016	0.000	0.000	0.000	0.001	0.000	0.001	0.022
19	-	-	-	0.00	0.0	0.0404	11	9	0.006	0	y	0.008	0.000	0.001	0.000	0.003	0.000	0.003	0.028
20	-	-	-	0.00	0.0	0.2480	16	0	0.000	0	y	0.228	0.000	0.005	0.001	0.018	0.000	0.018	0.446
21	-	-	-	0.00	0.0	0.0071	23	0	0.000	0	y	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000
22	-	-	-	0.00	0.0	0.0102	29	0	0.000	0	y	0.019	0.000	0.001	0.008	0.011	0.001	0.003	0.006
23	Compartment	1.19	1.18	1.00	17.5	0.0249	1	5	0.608	35	y	0.002	0.027	0.001	0.003	0.001	0.000	0.002	0.003
24	-	-	-	0.00	0.0	0.0187	2	8	0.002	0	y	0.002	0.000	0.001	0.002	0.001	0.000	0.001	0.002
25	-	-	-	0.00	0.0	0.2951	9	10	0.002	0	y	0.342	0.000	0.006	0.001	0.021	0.000	0.021	0.457
26	-	-	-	0.00	0.0	0.2951	10	0	0.000	0	y	0.049	0.000	0.006	0.001	0.021	0.000	0.021	0.192
27	-	-	-	0.00	0.0	0.0018	23	0	0.000	0	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
49	Air outlet duct	1.34	-	1.00	6.4	0.0267	9	5	0.031	b	y	0.031	0.001	0.001	0.000	0.002	0.000	0.002	0.041
50	Screws (duct ssy)	1.35	-	6.00	49.2	0.0080	2	10	0.001	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.001
51	Duct	1.36	1.35,34	1.00	4.8	1.8031	10	5	1.911	35	y	0.298	0.084	0.040	0.007	0.128	0.000	0.130	1.172
12	Bolster Screws	1.10	-	4.00	41.4	0.0053	2	10	0.001	b	y	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
13	Knee Bolster ssy	1.11/3	1.10,1.9	1.00	10.1	1.0257	0	0	0.000	c	y	1.125	0.047	0.023	0.004	0.073	0.000	0.074	1.547
28	Mounting Spikes	1.20	1.19,1.11	4.00	12.8	0.0053	9	5	0.007	b	y	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.008
29	Retainer Clip	1.22	1.20	3.00	9.6	0.0044	9	5	0.005	b	y	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.007
30	Unfasten Ash Tray	1.23	1.22	3.00	11.2	0.0000	0	0	0.000	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
58	Drv door sens mnt	1.43	-	1.00	3.9	0.0027	9	5	0.004	b	y	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004
59	-	-	-	0.00	0.0	0.0027	1	10	0.000	b	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	-	-	-	0.00	0.0	0.0027	9	5	0.004	b	y	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004
61	Sensor spring	1.44	1.43	1.00	3.8	0.0031	2	7	0.003	b	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
62	Pass door sens mnt	1.45	-	1.00	3.9	0.0027	9	5	0.004	b	y	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004
63	-	-	-	0.00	0.0	0.0027	1	10	0.000	b	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	-	-	-	0.00	0.0	0.0027	9	5	0.004	b	y	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004
65	Sensor spring	1.46	1.45	1.00	3.8	0.0031	2	7	0.003	b	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	GM C/K Truck Dash	1.0	-14.2931	-1.46561	0	0	0.0	-1.466	-14.29	-44.3	-44.3448
2	-	-	-14.2931	-1.46561	0	0	0.0	-1.466	-14.29	-44.3	0.0000
16	Inst Plate Bezel ssy	1.14/10	-12.9569	-1.35812	-0.31	-1.34396	29.5	-1.665	-14.3	-44.6	-0.2231
40	screws (clust ssy)	1.32	-12.9562	-1.35775	-0.22	-0.00025	56.5	-1.889	-14.3	-44.8	-0.2229
41	Instrument Cluster	1.33	-12.9082	-1.35744	200	0	61.9	198.1	-14.25	155	200.0994
42	-	-	-12.9016	-1.3551	0	0	61.9	198.1	-14.25	155	0.0221
43	-	-	-12.6554	-1.34851	0	0	61.9	198.1	-14	156	0.7451
44	-	-	-11.7509	-1.29394	0	0	61.9	198.1	-13.1	159	2.7681
45	-	-	-11.5861	-1.2814	0	0	61.9	198.1	-12.93	159	0.5069
46	-	-	-11.5854	-1.28093	0	0	61.9	198.1	-12.93	159	0.0027
47	-	-	-11.5823	-1.27944	0	0	61.9	198.1	-12.93	159	0.0108
48	-	-	-11.4934	-1.2763	0	0	61.9	198.1	-12.84	160	0.2698
17	Temp Ctrl/HVAC	1.17	-11.4525	-1.27558	135	0	78.6	333	-12.8	295	134.9843
18	-	-	-11.4357	-1.27459	0	0	78.6	333	-12.78	295	0.0516
19	-	-	-11.4274	-1.27176	0	0	78.6	333	-12.77	295	0.0277
20	-	-	-11.1992	-1.2544	0	0	78.6	333	-12.54	295	0.7018
21	-	-	-11.1984	-1.2539	0	0	78.6	333	-12.54	295	0.0028
22	-	-	-11.1782	-1.25318	0	0	78.6	333	-12.52	295	0.0614
23	Compartment	1.19	-11.149	-1.25144	34.9	0	96.1	367.9	-12.49	330	34.9435
24	-	-	-11.1468	-1.25013	0	0	96.1	367.9	-12.49	330	0.0079
25	-	-	-10.8044	-1.22948	0	0	96.1	367.9	-12.15	331	1.0479
26	-	-	-10.7557	-1.20882	0	0	96.1	367.9	-12.1	332	0.1667
27	-	-	-10.7555	-1.20869	0	0	96.1	367.9	-12.1	332	0.0007
49	Air outlet duct	1.34	-10.7232	-1.20683	-0.01	-0.00196	102.5	367.9	-12.07	332	0.0809
50	Screws (duct ssy)	1.35	-10.7223	-1.20627	-0.41	-0.00038	151.7	367.5	-12.07	331	-0.4068
51	Duct	1.36	-10.3407	-1.08005	35	0	156.5	402.6	-11.69	368	36.2310
12	Bolster Screws	1.10	-10.34	-1.07968	-0.34	-0.00025	197.9	402.3	-11.69	367	-0.3429
13	Knee Bolster ssy	1.11/3	-9.16739	-1.00788	-0.13	-1.17675	208.0	402.2	-11.69	367	-0.0657
28	Mounting Spikes	1.20	-9.16089	-1.0075	-0.1	-0.00043	220.8	402.1	-11.68	367	-0.0798
29	Retainer Clip	1.22	-9.15573	-1.00719	-0.07	-9.8E-05	230.4	402	-11.68	367	-0.0576
30	Unfasten Ash Tray	1.23	-9.15573	-1.00719	-0.09	0	241.6	401.9	-11.68	367	-0.0933
58	Drv door sens mnt	1.43	-9.15244	-1.007	-0.03	-0.00025	245.5	401.9	-11.68	367	-0.0191
59	-	-	-9.15218	-1.00682	0	-0.00012	245.5	401.9	-11.68	367	0.0009
60	-	-	-9.14889	-1.00663	0	-0.00025	245.5	401.9	-11.67	367	0.0134
61	Sensor spring	1.44	-9.14843	-1.00641	-0.03	-0.00024	249.3	401.9	-11.67	367	-0.0304
62	Pass door sens mnt	1.45	-9.14514	-1.00623	-0.03	-0.00025	253.2	401.9	-11.67	367	-0.0191
63	-	-	-9.14487	-1.00604	0	-0.00012	253.2	401.9	-11.67	367	0.0009
64	-	-	-9.14158	-1.00585	0	-0.00025	253.2	401.9	-11.67	367	0.0134
65	Sensor spring	1.46	-9.14112	-1.00564	-0.03	-0.00024	257.0	401.8	-11.67	367	-0.0304

E1 C/K Dash Optimized Sequence

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
66	Unfasten Harness	1.47	-	3.00	96.3	0.0000	0	0	0.000	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
67	Wire Harness	1.51	(1.47-43,36,33,23,19,17)	1.00	6.7	1.3333	1	5	2.444	150	y	0.117	0.108	0.057	0.167	0.067	0.013	0.096	0.160
68	-	-	-	0.00	0.0	1.3333	9	8	0.033	0	y	1.547	0.001	0.029	0.005	0.095	0.000	0.096	2.067
69	-	-	-	0.00	0.0	0.8333	16	0	0.000	0	y	0.767	0.000	0.018	0.003	0.059	0.000	0.060	1.500
52	Comp I/P Cluster	1.37	1.14	1.00	8.8	0.1702	10	5	0.200	b	y	0.028	0.009	0.004	0.001	0.012	0.000	0.012	0.111
32	Defl. ssy, out	1.25/22	-	1.00	10.1	0.1129	0	0	0.000	c	y	0.110	0.006	0.002	0.000	0.008	0.000	0.008	0.156
3	Fuse Block Cover	1.1/2	-	0.00	9.0	0.0458	0	0	0.000	d		0.049	0.002	0.001	0.000	0.003	0.000	0.003	0.064
4	Emerg. Brake Hndl.	1.2	-	1.00	11.6	0.0249	18	5	0.030	b		0.013	0.001	0.001	0.000	0.002	0.000	0.002	0.047
5	Emerg. Brake Cable	1.3	1.2	1.00	9.3	0.0444	2	5	0.027	c		0.005	0.001	0.002	0.006	0.002	0.000	0.003	0.005
6	-	-	-	1.00	0.0	0.0222	18	7	0.044	c		0.012	0.002	0.000	0.000	0.002	0.000	0.002	0.042
7	Duct LH	1.4	-	1.00	10.1	0.0151	9	5	0.022	b		0.018	0.001	0.000	0.000	0.001	0.000	0.001	0.023
8	Drv Side Foam	1.5	-	1.00	5.0	0.0013	13	5	0.002	b		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
9	Duct RH	1.6	-	1.00	10.1	0.0151	9	5	0.022	b		0.018	0.001	0.000	0.000	0.001	0.000	0.001	0.023
10	Pass Side Foam	1.7	-	1.00	5.0	0.0013	13	5	0.002	b		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
11	Rubber Dash Cush.	1.8	-	2.00	10.0	0.0027	23	5	0.004	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	Cup Holder Retainer	1.12	1.11	1.00	20.4	0.0031	9	5	0.004	b		0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.005
15	Cup Holder ssy	1.13/7	1.12	1.00	3.8	0.3711	0	0	0.000	c		0.365	0.016	0.009	0.003	0.026	0.000	0.027	0.494
31	Ash Tray ssy	1.24/21	1.23	1.00	4.8	0.3213	0	0	0.000	c		0.337	0.014	0.008	0.005	0.022	0.000	0.023	0.450
33	Defl. ssy, in	1.26/24	-	1.00	10.1	0.3213	0	0	0.000	c		0.337	0.014	0.008	0.005	0.022	0.000	0.023	0.450
34	Track Screws	1.27	1.11	3.00	32.1	0.0040	2	10	0.000	b		0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
35	Drink Hol Slide Trck	1.28	1.27	1.00	3.8	0.1551	1	1	0.008	b		0.014	0.000	0.007	0.019	0.008	0.002	0.011	0.019
36	-	-	-	0.00	0.0	0.0000	0	8	0.016	b		0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
37	Plas. Wrapper, sm	1.29	1.11	3.00	18.0	0.0013	9	5	0.001	b		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.002
38	Plas. Wrapper, lg	1.30	1.28	1.00	6.0	0.0004	9	5	0.000	b		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
39	Nut-I/P Carrier	1.31	1.28	2.00	22.8	0.0062	5	8	0.000	b		0.016	0.000	0.000	0.001	0.002	0.000	0.001	0.011
53	Plunger	1.38	-	2.00	13.4	0.0027	9	5	0.004	b		0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004
54	Plunger Base	1.39	1.38	2.00	7.6	0.0027	9	5	0.004	b		0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004
55	Liner ssy	1.40	1.39	1.00	3.2	0.0000	0	0	0.000	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
56	Nut I/P Carrier	1.41	-	1.00	13.5	0.0031	5	8	0.000	b		0.008	0.000	0.000	0.001	0.001	0.000	0.000	0.005
57	Slide Track Nut	1.42	1.28	1.00	13.5	0.0031	5	8	0.000	b		0.008	0.000	0.000	0.001	0.001	0.000	0.000	0.005
70	Base	Base	-	1.00	4.8	0.2244	1	1	1.290	300		0.020	0.058	0.010	0.028	0.011	0.002	0.016	0.027
71	-	-	-	0.00	0.0	4.1453	2	5	5.070	0		0.427	0.223	0.178	0.518	0.207	0.041	0.298	0.497
72	-	-	-	0.00	0.0	0.0107	9	5	0.711	0		0.012	0.031	0.000	0.000	0.001	0.000	0.001	0.017
73	-	-	-	0.00	0.0	4.7129	16	10	0.006	0		4.336	0.000	0.104	0.019	0.335	0.000	0.339	8.483
74	-	-	-	0.00	0.0	0.1213	23	0	0.000	0		0.013	0.000	0.003	0.000	0.009	0.000	0.009	0.000

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
66	Unfasten Harness	1.47	-9.14112	-1.00564	-0.8	0	353.3	401	-11.67	366	-0.8025
67	Wire Harness	1.51	-8.9029	-0.9123	150	0	360.0	551.1	-11.43	517	150.7522
68	-	-	-7.35479	-0.81897	0	0	360.0	551.2	-9.881	522	4.7377
69	-	-	-6.58812	-0.76064	0	0	360.0	551.2	-9.114	524	2.3583
52	Comp I/P Cluster	1.37	-6.55124	-0.74872	0.04	-0.01254	368.8	551.3	-9.09	524	0.1223
32	Defl. ssy, out	1.25/22	-6.43534	-0.74082	-0.09	-0.11635	378.9	551.2	-9.09	524	-0.0821
3	Fuse Block Cover	1.1/2	-6.94384	-0.42149	-0.08	-0.0512	387.9	551.4	-9.65	522	-1.4380
4	Emerg. Brake Hndl.	1.2	-6.92922	-0.4205	-0.05	-0.00188	399.5	551.4	-9.637	522	-0.0102
5	Emerg. Brake Cable	1.3	-6.91792	-0.41872	-0.08	-0.01131	408.8	551.3	-9.637	522	-0.0775
6	-	-	-6.90449	-0.41783	-0	-0.01342	408.8	551.3	-9.637	522	0.0000
7	Duct LH	1.4	-6.88593	-0.41723	-0.06	-0.00131	418.9	551.2	-9.62	522	-0.0084
8	Drv Side Foam	1.5	-6.8852	-0.41717	-0.04	-0.00011	423.9	551.2	-9.619	522	-0.0387
9	Duct RH	1.6	-6.86663	-0.41657	-0.06	-0.00131	434.0	551.1	-9.602	522	-0.0084
10	Pass Side Foam	1.7	-6.8659	-0.41652	-0.04	-0.00011	439.0	551.1	-9.601	522	-0.0387
11	Rubber Dash Cush.	1.8	-6.86544	-0.41641	-0.08	-0.00022	449.0	551	-9.601	522	-0.0825
14	Cup Holder Retainer	1.12	-6.86162	-0.41628	-0.17	-0.00026	469.4	550.8	-9.597	522	-0.1544
15	Cup Holder ssy	1.13/7	-6.47674	-0.40144	-0.05	-0.38488	473.2	550.8	-9.597	522	-0.0317
31	Ash Tray ssy	1.24/21	-6.12077	-0.38859	-0.05	-0.35597	478.0	550.8	-9.597	522	-0.0400
33	Defl. ssy, in	1.26/24	-5.7648	-0.37573	-0.1	-0.35597	488.1	550.7	-9.597	522	-0.0842
34	Track Screws	1.27	-5.76388	-0.37557	-0.27	-0.00019	520.2	550.4	-9.597	522	-0.2646
35	Drink Hol Slide Trck	1.28	-5.73049	-0.36937	-0.01	-0.00702	524.0	550.4	-9.57	522	0.0723
36	-	-	-5.72977	-0.36937	0	-0.00072	524.0	550.4	-9.57	522	0.0000
37	Plas. Wrapper, sm	1.29	-5.72816	-0.36932	-0.15	-8.8E-05	542.0	550.3	-9.569	522	-0.1433
38	Plas. Wrapper, lg	1.30	-5.72762	-0.3693	-0.05	-2.9E-05	548.0	550.2	-9.568	522	-0.0478
39	Nut-I/P Carrier	1.31	-5.71035	-0.36905	-0.18	-0.00017	570.8	550	-9.551	521	-0.1276
53	Plunger	1.38	-5.70709	-0.36894	-0.11	-0.00022	584.2	549.9	-9.548	521	-0.0983
54	Plunger Base	1.39	-5.70383	-0.36884	-0.06	-0.00022	591.8	549.9	-9.545	521	-0.0500
55	Liner ssy	1.40	-5.70383	-0.36884	-0.03	0	595.0	549.8	-9.545	521	-0.0267
56	Nut I/P Carrier	1.41	-5.69519	-0.36871	-0.11	-9.1E-05	608.5	549.7	-9.537	521	-0.0813
57	Slide Track Nut	1.42	-5.68655	-0.36859	-0.11	-9.1E-05	622.0	549.6	-9.528	521	-0.0813
70	Base	Base	-5.58068	-0.35961	300	0	626.8	849.6	-9.422	821	300.2866
71	-	-	-4.41247	-0.1938	0	0	626.8	849.8	-8.254	825	3.6704
72	-	-	-4.36876	-0.19337	0	0	626.8	849.8	-8.21	825	0.1316
73	-	-	-0.01383	-0.00485	0	0	626.8	850	-3.855	838	13.2533
74	-	-	0	0	0	0	626.8	850	-3.841	838	0.0463

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SI	MET EOL SI	Rec \$
1	Fuse Block Cover	1.1/2	-	0.00	0.0	0.0000	0	0	0.000	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Fuse Info Sticker	2.1	1.1	1.00	5.0	0.0004	30	1	0.000	c	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Spring Clip	2.2	1.1	1.00	7.8	0.0013	1	8	0.000	b	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Fuses	2.3	1.1	4.00	31.2	0.0036	3	5	0.004	c	y	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.002
5	-	-	-	0.00	0.0	0.0018	11	10	0.001	c	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
6	Fuse Gripper	2.4	1.1	1.00	5.0	0.0027	9	5	0.004	b		0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.004
7	Fuse Cover	2.5	2.4-1,1.1	1.00	3.8	0.0360	9	5	0.040	b		0.042	0.002	0.001	0.000	0.003	0.000	0.003	0.056

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SI	MET EOL SI	Rec \$
1	Knee Bolster ssy	1.11/3	1.10,1.9	1.00	0.0	0.0000	0	0	0.000	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Vent Base	3.1	1.11	1.00	3.8	0.0329	10	5	0.037	b		0.005	0.002	0.001	0.000	0.002	0.000	0.002	0.021
3	Vent	3.2	3.1	1.00	5.0	0.0688	9	5	0.081	b		0.080	0.004	0.002	0.000	0.005	0.000	0.005	0.107
4	Mounting Spikes	3.3	1.11	2.00	10.0	0.0027	16	5	0.004	b		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005
5	Bolster Plas. Plate	3.4	3.3	1.00	3.8	0.0351	16	5	0.004	b		0.032	0.000	0.001	0.000	0.002	0.000	0.003	0.063
6	Foam Pad, lg	3.5	1.11	1.00	5.0	0.0040	23	5	0.004	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	Foam Pad, sm	3.6	1.11	1.00	5.0	0.0027	23	5	0.003	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Mounting Clips	3.7	1.11	7.00	69.3	0.0093	16	5	0.012	b		0.009	0.001	0.000	0.000	0.001	0.000	0.001	0.017
9	Separate glued joint	3.8	1.11	1.00	41.0	0.0000	0	0	0.000	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Styrofoam Pad	3.9	1.11	1.00	3.8	0.0200	13	5	0.020	c		0.010	0.001	0.000	0.000	0.001	0.000	0.001	0.016
11	Bolster	3.10	3.9-1	1.00	3.8	0.8502	9	5	0.911	b		0.986	0.040	0.019	0.003	0.060	0.000	0.061	1.318

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SI	MET EOL SI	Rec \$
1	Cup Holder ssy	1.13/7	1.12	1.00	0.0	0.0000	0	0	0.000	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Swing Arm Ret.	7.1	1.13	1.00	5.0	0.0080	16	5	0.011	b		0.007	0.000	0.000	0.000	0.001	0.000	0.001	0.014
3	Swing Arm ssy	7.2/8	7.1	1.00	3.8	0.1396	0	0	0.000	c		0.134	0.006	0.003	0.001	0.010	0.000	0.010	0.176
4	Spring	7.3	1.13	1.00	3.8	0.0013	1	8	0.000	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Rivets	7.4	1.13	2.00	8.2	0.0027	2	10	0.000	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Handle	7.5	7.4	1.00	3.8	0.0520	9	5	0.056	b		0.060	0.002	0.001	0.000	0.004	0.000	0.004	0.081
7	Front Foam Guide	7.6	7.5	1.00	3.8	0.0036	23	5	0.004	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Rivets	7.7	1.13	1.00	11.3	0.0013	2	10	0.000	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Foam Bracket	7.8	7.7	1.00	3.8	0.0036	23	5	0.000	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Rear Foam Guide	7.9	7.8	1.00	3.8	0.0080	23	5	0.008	c		0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000
11	Rivets	7.10	1.13	4.00	37.0	0.0053	2	10	0.001	b		0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
12	Right Guide Rail	7.11	7.10	1.00	3.8	0.0071	16	5	0.009	b		0.007	0.000	0.000	0.000	0.001	0.000	0.001	0.013
13	Rivets	7.12	1.13	4.00	37.0	0.0053	2	10	0.001	b		0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001
14	Left Guide Rail	7.13	7.12	1.00	3.8	0.0071	16	5	0.009	b		0.007	0.000	0.000	0.000	0.001	0.000	0.001	0.013
15	Base	7.15	7.12-1	1.00	3.8	0.1262	9	5	0.131	b		0.146	0.006	0.003	0.001	0.009	0.000	0.009	0.196

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Fuse Block Cover	1.1/2	-0.0512	-0.0032	0	0	0.0	-0.003	-0.051	-0.16	-0.1568
2	Fuse Info Sticker	2.1	-0.05112	-0.00317	-0.04	-8.8E-05	5.0	-0.045	-0.051	-0.2	-0.0417
3	Spring Clip	2.2	-0.05098	-0.00308	-0.06	-6.5E-05	12.8	-0.11	-0.051	-0.26	-0.0645
4	Fuses	2.3	-0.04716	-0.00283	-0.26	-0.00385	44.0	-0.369	-0.051	-0.52	-0.2600
5	-	-	-0.04679	-0.00271	-0	-0.00038	44.0	-0.369	-0.051	-0.52	0.0000
6	Fuse Gripper	2.4	-0.04368	-0.00144	-0.04	-0.00022	49.0	-0.406	-0.048	-0.55	-0.0276
7	Fuse Cover	2.5	0	0	0.02	-0.00257	52.8	-0.38	-0.007	-0.4	0.1489

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Knee Bolster ssy	1.11/3	-1.17675	-0.04103	0	0	0.0	-0.041	-1.177	-3.57	-3.5713
2	Vent Base	3.1	-1.16955	-0.03971	-0.01	-0.00237	3.8	-0.05	-1.172	-3.57	0.0055
3	Vent	3.2	-1.08587	-0.03696	0.07	-0.00509	8.8	0.018	-1.093	-3.26	0.3035
4	Mounting Spikes	3.3	-1.08325	-0.03685	-0.08	-0.00021	18.8	-0.061	-1.091	-3.33	-0.0712
5	Bolster Plas. Plate	3.4	-1.05063	-0.03545	0.03	-0.00094	22.6	-0.028	-1.059	-3.21	0.1279
6	Foam Pad, lg	3.5	-1.05	-0.03529	-0.04	-0.00063	27.6	-0.069	-1.059	-3.25	-0.0417
7	Foam Pad, sm	3.6	-1.04958	-0.03518	-0.04	-0.00042	32.6	-0.111	-1.059	-3.29	-0.0417
8	Mounting Clips	3.7	-1.04041	-0.03481	-0.56	-0.00075	101.9	-0.671	-1.051	-3.82	-0.5351
9	Separate glued joint	3.8	-1.04041	-0.03481	-0.34	0	142.9	-1.013	-1.051	-4.17	-0.3417
10	Styrofoam Pad	3.9	-1.02975	-0.03401	-0.03	-0.01066	146.7	-1.045	-1.051	-4.2	-0.0317
11	Bolster	3.10	0	0	1.29	-0.05879	150.5	0.275	-0.08	0.04	4.2330

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Cup Holder ssy	1.13/7	-0.38488	-0.01484	0	0	0.0	-0.015	-0.385	-1.17	-1.1695
2	Swing Arm Ret.	7.1	-0.37702	-0.01452	-0.03	-0.00065	5.0	-0.042	-0.378	-1.17	-0.0053
3	Swing Arm ssy	7.2/8	-0.23553	-0.00894	-0.04	-0.14149	8.8	-0.073	-0.378	-1.21	-0.0317
4	Spring	7.3	-0.23524	-0.00889	-0.03	-6.5E-05	12.6	-0.105	-0.377	-1.24	-0.0308
5	Rivets	7.4	-0.23462	-0.00878	-0.07	-0.00013	20.8	-0.173	-0.377	-1.3	-0.0664
6	Handle	7.5	-0.17165	-0.0067	0.05	-0.00359	24.6	-0.122	-0.318	-1.07	0.2292
7	Front Foam Guide	7.6	-0.17109	-0.00656	-0.03	-0.00056	28.4	-0.153	-0.318	-1.11	-0.0317
8	Rivets	7.7	-0.17078	-0.00651	-0.09	-6.3E-05	39.7	-0.247	-0.317	-1.2	-0.0932
9	Foam Bracket	7.8	-0.17036	-0.00636	-0.03	-0.00042	43.5	-0.279	-0.317	-1.23	-0.0317
10	Rear Foam Guide	7.9	-0.16909	-0.00604	-0.03	-0.00126	47.3	-0.311	-0.317	-1.26	-0.0317
11	Rivets	7.10	-0.16785	-0.00583	-0.31	-0.00025	84.3	-0.618	-0.316	-1.57	-0.3045
12	Right Guide Rail	7.11	-0.16089	-0.00555	-0.02	-0.00055	88.1	-0.637	-0.31	-1.57	0.0007
13	Rivets	7.12	-0.15965	-0.00533	-0.31	-0.00025	125.1	-0.944	-0.309	-1.87	-0.3045
14	Left Guide Rail	7.13	-0.15269	-0.00505	-0.02	-0.00055	128.9	-0.963	-0.303	-1.87	0.0007
15	Base	7.15	0	0	0.16	-0.00855	132.7	-0.794	-0.158	-1.27	0.6015

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Swing Arm ssy	7.2/8	7.1	1.00	3.8	0.0000	0	0	0.000	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Felt Bumper	8.1	7.2	1.00	6.4	0.0013	30	1	0.000	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Rubber Cup Mat	8.2	7.2	1.00	5.0	0.0191	23	5	0.019	b		0.002	0.001	0.000	0.000	0.001	0.000	0.001	0.000
4	Foam Cup Guide	8.3	7.2	1.00	14.8	0.0027	23	5	0.003	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Bearing Clip	8.4	7.2	1.00	3.2	0.0013	9	5	0.002	b		0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.002
6	Rubber Knob	8.5	7.2	1.00	6.4	0.0013	23	5	0.001	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	Felt Bearing	8.6	7.2	1.00	5.0	0.0013	30	1	0.000	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Part Sticker	8.7	7.2	1.00	5.0	0.0004	30	1	0.000	c		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Swing Arm	8.8	8.7-1	1.00	3.8	0.1120	9	5	0.120	b		0.130	0.005	0.002	0.000	0.008	0.000	0.008	0.174

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Inst Plate Bezel ssy	1.14/10	-	1.00	0.0	0.0000	0	0	0.000	a	y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Dome Light switch	10.4	1.14	1.00	3.2	0.2200	9	5	0.231	10	y	0.255	0.010	0.005	0.001	0.016	0.000	0.016	0.341
9	Cargo Lamp switch	10.9	1.14	1.00	3.2	0.0289	9	5	0.036	10	y	0.034	0.002	0.001	0.000	0.002	0.000	0.002	0.045
2	Instrument Bezel	10.3	1.14	1.00	3.8	0.0133	1	1	0.090	45	y	0.001	0.004	0.001	0.002	0.001	0.000	0.001	0.002
3	-	-	-	0.00	0.0	0.0013	2	5	1.372	0	y	0.000	0.060	0.000	0.000	0.000	0.000	0.000	0.000
4	-	-	-	0.00	0.0	0.1409	9	8	0.002	0	y	0.163	0.000	0.003	0.001	0.010	0.000	0.010	0.218
5	-	-	-	0.00	0.0	0.2507	10	0	0.000	0	y	0.041	0.000	0.006	0.001	0.018	0.000	0.018	0.163
6	-	-	-	0.00	0.0	0.8249	16	0	0.000	0	y	0.759	0.000	0.018	0.003	0.059	0.000	0.059	1.485
7	-	-	-	0.00	0.0	0.0556	23	0	0.000	0	y	0.006	0.000	0.001	0.000	0.004	0.000	0.004	0.000

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Ash Tray ssy	1.24/21	1.23	1.00	0.0	0.0000	0	0	0.000	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Ash Tray	21.4	-	1.00	3.8	0.0880	9	5	0.089	b		0.102	0.004	0.002	0.000	0.006	0.000	0.006	0.136
7	Rivets for Base	21.8	1.24	2.00	8.2	0.0027	2	10	0.003	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Rubber Buttons	21.9	1.24	2.00	5.0	0.0053	23	5	0.005	b		0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Base	21.10	21.9,8	1.00	3.8	0.1000	9	5	0.111	b		0.116	0.005	0.002	0.000	0.007	0.000	0.007	0.155
2	Foam Pad	21.1	1.24	1.00	5.0	0.0013	23	5	0.001	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Rivets for Plate	21.2	1.24	1.00	12.4	0.0013	2	10	7E-05	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Plate	21.3	21.2	1.00	3.8	0.0200	1	10	0.000	b		0.002	0.000	0.001	0.003	0.001	0.000	0.001	0.002
6	Springs	21.7	1.24	2.00	12.2	0.0027	2	7	0.003	b		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Cover	21.11	21.10-21.1	1.00	3.8	0.1000	9	5	0.111	b		0.116	0.005	0.002	0.000	0.007	0.000	0.007	0.155

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Swing Arm ssy	7.2/8	-0.14149	-0.00558	-0.03	0	3.8	-0.037	-0.141	-0.46	-0.4617
2	Felt Bumper	8.1	-0.14125	-0.00553	-0.05	-0.00023	10.2	-0.091	-0.141	-0.52	-0.0533
3	Rubber Cup Mat	8.2	-0.13823	-0.00476	-0.04	-0.00126	15.2	-0.131	-0.14	-0.55	-0.0356
4	Foam Cup Guide	8.3	-0.13781	-0.00466	-0.12	-0.00042	30.0	-0.255	-0.14	-0.67	-0.1233
5	Bearing Clip	8.4	-0.13618	-0.0046	-0.02	-0.00011	33.2	-0.279	-0.138	-0.69	-0.0200
6	Rubber Knob	8.5	-0.13597	-0.00455	-0.05	-8.7E-05	39.6	-0.333	-0.138	-0.75	-0.0529
7	Felt Bearing	8.6	-0.13574	-0.0045	-0.04	-0.00023	44.6	-0.374	-0.138	-0.79	-0.0417
8	Part Sticker	8.7	-0.13565	-0.00448	-0.04	-8.8E-05	49.6	-0.416	-0.138	-0.83	-0.0417
9	Swing Arm	8.8	0	0	0.14	-0.00774	53.4	-0.27	-0.01	-0.3	0.5301

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Inst Plate Bezel ssy	1.14/10	-1.33619	-0.10749	0	0	0.0	-0.107	-1.336	-4.12	-4.1160
8	Dome Light switch	10.4	-1.07082	-0.09209	9.97	0	3.2	9.881	-1.071	6.67	10.7848
9	Cargo Lamp switch	10.9	-1.03574	-0.09007	9.97	0	6.4	19.86	-1.036	16.7	10.0806
2	Instrument Bezel	10.3	-1.03037	-0.08913	45	0	10.2	64.83	-1.03	61.7	44.9854
3	-	-	-0.96987	-0.08904	0	0	10.2	64.83	-0.97	61.9	0.1816
4	-	-	-0.80637	-0.07918	0	0	10.2	64.84	-0.806	62.4	0.5004
5	-	-	-0.76501	-0.06163	0	0	10.2	64.85	-0.765	62.6	0.1416
6	-	-	-0.00611	-0.00389	0	0	10.2	64.91	-0.006	64.9	2.3344
7	-	-	0	0	0	0	10.2	64.92	0	64.9	0.0222

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Ash Tray ssy	1.24/21	-0.35597	-0.01285	0	0	0.0	-0.013	-0.356	-1.08	-1.0808
5	Ash Tray	21.4	-0.24963	-0.00933	0.1	-0.00585	3.8	0.095	-0.255	-0.67	0.4097
7	Rivets for Base	21.8	-0.2489	-0.00923	-0.07	-0.00023	12.0	0.027	-0.255	-0.74	-0.0664
8	Rubber Buttons	21.9	-0.24806	-0.00901	-0.04	-0.00035	17.0	-0.014	-0.254	-0.78	-0.0400
9	Base	21.10	-0.12677	-0.00501	0.12	-0.00709	20.8	0.113	-0.14	-0.31	0.4699
2	Foam Pad	21.1	-0.12656	-0.00496	-0.04	-8.8E-05	25.8	0.072	-0.14	-0.35	-0.0412
3	Rivets for Plate	21.2	-0.12626	-0.00491	-0.1	-6E-05	38.2	-0.031	-0.14	-0.45	-0.1024
4	Plate	21.3	-0.12199	-0.00411	-0.03	-0.00087	42.0	-0.06	-0.137	-0.47	-0.0183
6	Springs	21.7	-0.12129	-0.004	-0.1	-0.00021	54.2	-0.161	-0.136	-0.57	-0.0998
10	Cover	21.11	0	0	0.12	-0.00709	58.0	-0.034	-0.022	-0.1	0.4699

Step	Part Name	Part #	Precedence	Rpt Cnt	Dis Time	Part(s) Wt.	Mat'l Code	Proc. Code	Prod'n Factor	Dest Code	Toxic Rest?	MET Conv	MET Prod	MET Rec	MET EOL NL	MET EOL NI	MET EOL SL	MET EOL SI	Rec \$
1	Defl. ssy, out	1.25/22	-	1.00	0.0	0.0000	0	0	0.000	a		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Base	22.1	1.25	1.00	3.8	0.0209	0	5	0.025	b		0.003	0.001	0.000	0.000	0.001	0.000	0.002	0.014
3	Vent Rest	22.2	22.1	1.00	3.8	0.0920	9	5	0.105	b		0.107	0.005	0.002	0.000	0.007	0.000	0.007	0.143

[illegible]

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Defl. ssy, out	1.25/22	-0.11635	-0.00452	0	0	0.0	-0.005	-0.116	-0.35	-0.3536
2	Base	22.1	-0.11172	-0.00368	-0.02	-0.00155	3.8	-0.022	-0.113	-0.36	-0.0080
3	Vent Rest	22.2	0	0	0.11	-0.00666	7.6	0.093	-0.008	0.07	0.4298

Step	Part Name	Part #	MET Rest	Rest Disp \$	Profit (step)	MET (step)	Time (cum.)	Profit (cum.)	MET (cum.)	Eco\$ (cum.)	Effect
1	Defl. ssy, in	1.26/24	-0.08233	-0.0034	0	0	0.0	-0.003	-0.082	-0.25	-0.2504
2	Vent Base	24.1	-0.03588	-0.00187	0.03	-0.0028	3.8	0.026	-0.039	-0.09	0.1601
3	Case Top	24.2	-0.0308	-0.00174	-0.07	-0.00153	12.6	-0.043	-0.035	-0.15	-0.0577
4	Slider	24.3	-0.03051	-0.00169	-0.03	-8.8E-05	15.8	-0.068	-0.035	-0.17	-0.0252
5	Base	24.4	-0.02589	-0.00085	-0.02	-0.00155	19.6	-0.086	-0.032	-0.18	-0.0080
6	Gear	24.5	-0.02428	-0.0008	-0.04	-8.8E-05	24.6	-0.125	-0.03	-0.22	-0.0350
7	Fins	24.6	-0.00161	-5.3E-05	0.03	-0.00135	24.6	-0.096	-0.009	-0.12	0.0936
8	Connecor Rod	24.7	0	0	0	-8.8E-05	24.6	-0.093	-0.007	-0.12	0.0067

Appendix F

IBM PS/2 Yield Sheets for Optimization Procedure

F1 IBM PS/2 Yield Sheets for Optimization Procedure

A-Drive		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
3.2	8.8	6.27990
Sum	33.2	6.10245
	Yield	661.71186

C-Drive		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
3.5	8.8	16.55528
Sum	33.2	16.37783
	Yield	1775.90891

AAAAAAAAAAAAAAAA

Power Supply		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
1.7	21.3	-0.17340
1.8	4.2	3.59551
Sum	49.9	3.24467
	Yield	234.08426

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
1.6	12.0	0.29157
3.1	8.8	0.99916
Sum	45.2	1.11328
	Yield	88.66809

Mother Board		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
1.6	12.0	0.29157
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76196
Sum	108.4	5.94685
	Yield	197.49670

C-Drive Controller		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
3.5	8.8	16.55528
3.6	3.2	0.60008
Sum	36.4	16.97791
	Yield	1679.13386

Face Plate		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	56.6	0.21961
	Yield	13.96811

Fan		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
3.9	3.2	-0.00595
4.4	5.3	-0.04651
4.5	19.2	-0.15726
4.6	3.8	1.22821
Sum	55.9	0.84103
	Yield	54.16316

Lock		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
1.14	13.6	-0.11273
1.15	3.8	-0.03109
1.16	3.8	-0.02527
1.17	7.8	-0.06442
1.18	3.8	0.47740
Sum	53.4	-0.41095
	Yield	-27.70451

Base		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
1.3	6.4	-0.04115
1.4	21.9	-0.17814
1.6	12.0	0.29157
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76173
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	302.1	-0.27856
	Yield	-3.31952

A-Drive Controller		
Part #	Dis Time	Effect
1.1	20.2	-0.16833
1.2	4.2	-0.00912
3.2	8.8	6.27990
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	40.2	6.21745
	Yield	556.78631

A-Drive		
Part #	Dis Time	Effect
3.2	8.8	6.27990
Sum	8.8	6.27990
	Yield	2569.06111

AAAAAAAAAAAAAAAAAAAA

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
1.7	21.3	-0.17340
1.8	4.2	3.59551
Sum	25.5	3.42212
	Yield	483.12237

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
1.6	12.0	0.15683
3.1	8.8	0.99916
Sum	20.8	1.15599
	Yield	200.07489

Mother Board		
Part #	Dis Time	Effect
1.6	12.0	0.15683
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76196
Sum	84.0	5.98956
	Yield	256.88527

C-Drive Controller		
Part #	Dis Time	Effect
3.6	3.2	0.60008
Sum	3.2	0.60008
	Yield	675.00000

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

Fan		
Part #	Dis Time	Effect
3.9	3.2	-0.00595
4.4	5.3	-0.04651
4.5	19.2	-0.15726
4.6	3.8	1.22821
Sum	31.5	1.01848
	Yield	116.39799

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11273
1.15	3.8	-0.03109
1.16	3.8	-0.02527
1.17	7.8	-0.06442
1.18	3.8	0.47740
Sum	32.8	0.24390
	Yield	26.76962

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04115
1.4	21.9	-0.17814
1.6	12.0	0.15683
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76173
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	277.7	7.07123
	Yield	91.66886

A-Drive Controller		
Part #	Dis Time	Effect
3.2	8.8	6.27990
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	15.8	6.39490
	Yield	1457.06492

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
1.7	21.3	-0.17340
1.8	4.2	3.59551
Sum	25.5	3.42212
	Yield	483.12237

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
1.6	12.0	0.04634
3.1	8.8	0.99916
Sum	20.8	1.04550
	Yield	160.95178

Mother Board		
Part #	Dis Time	Effect
1.6	12.0	0.04634
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76196
Sum	84.0	5.87907
	Yield	251.96002

C-Drive Controller		
Part #	Dis Time	Effect
3.6	3.2	0.60008
Sum	3.2	0.60008
	Yield	675.09038
AAAAAAAAAAAAAA		

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

Fan		
Part #	Dis Time	Effect
3.9	3.2	-0.00595
4.4	5.3	-0.04651
4.5	19.2	-0.15726
4.6	3.8	1.22821
Sum	31.5	1.01848
	Yield	116.39799

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11273
1.15	3.8	-0.03109
1.16	3.8	-0.02527
1.17	7.8	-0.06442
1.18	3.8	0.47740
Sum	32.8	0.24390
	Yield	26.76662

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04115
1.4	21.9	-0.17814
1.6	12.0	0.04634
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76173
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	277.7	6.96074
	Yield	90.23652

A-Drive Controller		
Part #	Dis Time	Effect
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	7.0	0.11499
	Yield	59.13943

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
1.7	21.3	-0.17340
1.8	4.2	3.59551
Sum	25.5	3.42212
	Yield	483.12237
AAAAAAAAAAAAAAAA		

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
1.6	12.0	-0.00156
3.1	8.8	0.99916
Sum	20.8	0.99760
	Yield	172.66191

Mother Board		
Part #	Dis Time	Effect
1.6	12.0	-0.00156
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76196
Sum	84.0	5.83117
	Yield	248.90729

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Disassembly Stage 4

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

Fan		
Part #	Dis Time	Effect
3.9	3.2	-0.00595
4.4	5.3	-0.04651
4.5	19.2	-0.15726
4.6	3.8	1.22821
Sum	31.5	1.01848
	Yield	116.39799

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11273
1.15	3.8	-0.03109
1.16	3.8	-0.02527
1.17	7.8	-0.06442
1.18	3.8	0.47740
Sum	32.8	0.24390
	Yield	26.76962

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04115
1.4	21.9	-0.17814
1.6	12.0	-0.00156
1.7	21.3	-0.17340
1.8	4.2	3.59551
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76173
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	277.7	6.91285
	Yield	89.61560

A-Drive Controller		
Part #	Dis Time	Effect
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	7.0	0.11499
	Yield	59.13943

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
1.6	12.0	-0.00156
3.1	8.8	0.99916
Sum	20.8	0.99760
	Yield	172.66191
		AAAAAAAAAAAAAA

Mother Board		
Part #	Dis Time	Effect
1.6	12.0	-0.00156
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76196
Sum	58.5	2.40905
	Yield	148.24944

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

Fan		
Part #	Dis Time	Effect
3.9	3.2	-0.00595
4.4	5.3	-0.04651
4.5	19.2	-0.15726
4.6	3.8	1.22821
Sum	31.5	1.01848
	Yield	116.39799

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11273
1.15	3.8	-0.03109
1.16	3.8	-0.02527
1.17	7.8	-0.06442
1.18	3.8	0.47740
Sum	32.8	0.24390
	Yield	26.76662

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04115
1.4	21.9	-0.17814
1.6	12.0	-0.00156
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76173
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	252.2	3.49073
	Yield	49.82804

A-Drive Controller		
Part #	Dis Time	Effect
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	7.0	0.11499
	Yield	59.13943

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Mother Board		
Part #	Dis Time	Effect
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76196
Sum	46.5	2.41061
	Yield	186.62778

AAAAAAAAAAAAAAAA

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

Fan		
Part #	Dis Time	Effect
3.9	3.2	-0.00595
4.4	5.3	-0.04651
4.5	19.2	-0.15726
4.6	3.8	1.22821
Sum	31.5	1.01848
	Yield	116.39799

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11273
1.15	3.8	-0.03109
1.16	3.8	-0.02527
1.17	7.8	-0.06442
1.18	3.8	0.47740
Sum	32.8	0.24390
	Yield	26.76962

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04115
1.4	21.9	-0.17814
1.9	21.3	-0.17568
1.10	21.3	-0.17568
1.11	3.9	2.76173
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	240.2	3.49229
	Yield	52.34068

A-Drive Controller		
Part #	Dis Time	Effect
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	7.0	0.11499
	Yield	59.13943

Disassembly Stage 7

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Mother Board		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Disassembly Stage 7

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

Fan		
Part #	Dis Time	Effect
3.9	3.2	-0.00595
4.4	5.3	-0.04651
4.5	19.2	-0.15726
4.6	3.8	1.22821
Sum	31.5	1.01848
	Yield	116.39799
AAAAAAAAAAAAA		

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
Sum	32.8	0.24408
	Yield	26.78808

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04142
1.4	21.9	-0.17810
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	193.7	1.08168
	Yield	20.10346

A-Drive Controller		
Part #	Dis Time	Effect
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	7.0	0.11499
	Yield	59.13943

Disassembly Stage 8

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

Power Supply		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

Mother Board		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

Disassembly Stage 8

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

Fan		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
Sum	32.8	0.24408
	Yield	26.78

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04142
1.4	21.9	-0.17810
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	193.7	1.08168
	Yield	20.10346

A-Drive Controller		
Part #	Dis Time	Effect
3.3	3.2	-0.02636
3.4	3.8	0.14136
Sum	7.0	0.11499
	Yield	50.139

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Mother Board		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Disassembly Stage 9

Face Plate		
Part #	Dis Time	Effect
2.1	10.0	-0.08333
2.2	13.4	0.03945
2.3	8.8	0.44094
Sum	32.2	0.39706
	Yield	44.39165

AAAAAAAAAAAAAAAA

Fan		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
Sum	32.8	0.24408
	Yield	26.78908

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04142
1.4	21.9	-0.17810
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	193.7	1.08168
	Yield	20.10346

A-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Sys Spkr/Clock Bttry		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Mother Board		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Face Plate		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

Fan		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

Lock		
Part #	Dis Time	Effect
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
Sum	32.8	0.24408
Yield		

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04142
1.4	21.9	-0.17810
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.14	13.6	-0.11272
1.15	3.8	-0.03108
1.16	3.8	-0.02521
1.17	7.8	-0.06441
1.18	3.8	0.47750
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	193.7	1.08168
Yield		

A-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
Yield		

A-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Power Supply		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Sys Spkr/Clock Bitry		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Mother Board		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

C-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Part #	Dis Time	Effect
Sum	0.0	0.00000

Fan		
Part #	Dis Time	Effect
Sum	0.0	0.00000

Lock		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

A-Drive Controller		
Part #	Dis Time	Effect
Sum	0.0	0.00000
	Yield	

Base		
Part #	Dis Time	Effect
1.3	6.4	-0.04142
1.4	21.9	-0.17810
1.12	5.6	-0.03669
1.13	3.2	-0.02181
1.19	3.8	-0.02923
1.20	5.0	-0.04167
1.21	15.0	-0.12500
1.22	34.8	-0.29000
1.23	41.4	-0.34500
1.24	20.0	-0.16667
1.25	3.8	2.11319
Sum	160.9	0.83760
	Yield	18.74057

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