Total Cost Analysis of Pollution Prevention in Automotive Electrocoating

by

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ABSTRACT

A total cost analysis was conducted to evaluate a pollution prevention project in automotive electrocoating. The pollution prevention project was a manufacturing change from the current leaded, automobile electrocoating process to a lead-free electrocoating process. The main goals of the lead-free electrocoat project were reduced environmental impacts and costs. The higher materials costs of the project, however were perceived by industry to be an obstacle. Total cost analysis was expected to provide a better means of evaluating overall costs in the lead-free electrocoat project than conventional financial analyses.

The results of the total cost analysis showed that the lead-free electrocoat paint price was a pivotal input. A price less than a 0.3% increase over the leaded paint price resulted in the pollution prevention project being financially worthwhile, with the exclusion of liability and less tangible benefits. Incorporating these benefits resulted in the project being financially worthwhile at the estimated 9% price increase for lead-free paint if the liability and less tangible savings were valued at a couple million dollars over twenty years.

Total cost analysis provided more complete cost information than would a conventional financial analysis. Total cost analysis did not, however, replace decision making. Strategic considerations aside from costs were also important to automakers and automotive suppliers who implemented lead-free electrocoat systems.

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Chapter 1. Problem Statement and Historical Background

1.1 Problem Statement

Highly regulated throughout its history, the U.S. automobile industry has had extensive experience with command-and-control environmental regulations over the past twenty-five years. Such experience has prompted the industry to consider alternative solutions to environmental protection. Through pollution prevention initiatives, the auto industry can adopt a more proactive role of environmental stewardship by reducing pollution at its source. The high costs and technological limits of end-of-pipe controls have stimulated this interest, resulting in the redesign of products and processes to reduce the quantity of pollution generated. Since pollution can be viewed as another form of product and process waste, pollution prevention supports the goals of efficient and low-cost manufacturing. With expectations of regulatory relief, improved efficiency, and decreased environmental costs, the automotive companies are increasingly willing to explore pollution prevention initiatives.

The electrocoat operation, commonly called e-coat or ELPO, is an initial process stage of automotive painting which presents an opportunity for pollution prevention. The current electrocoat process is widely used in automotive assembly plants to coat vehicles with a lead-pigmented, electrically-charged paint that provides corrosion resistance and a base for further painting operations. Although the process meets all current environmental regulations, it incurs hazardous waste disposal costs and other environmental costs. Therefore, it may be advantageous to the automotive industry to remove the lead in the process. Although lead-free formulations have been developed, cost remains an important obstacle in changing to a lead-free electrocoat system. The current cost decisions focus on the higher price per gallon of the new, lead-free paint and exclude many of the environmental financial benefits of removing the lead. Some experts in the industry believe that using a total cost analysis model will provide a better means of evaluating overall costs in the lead-free electrocoat process and other pollution prevention initiatives.

The main problem to be addressed by this thesis is how pollution prevention opportunities are evaluated in automotive electrocoating. Specifically, this thesis investigates the merits of using total cost analysis to provide information in evaluating the lead-free electrocoat process. This investigation also includes policy and strategic implications of pollution prevention decisions in the U.S. automotive industry.

1.2 Brief History of Environmental Regulation in the U.S. Automotive Industry

Early environmental regulations are considered to be command-and-control due to such characteristics as inflexible standards, specified technologies versus performance standards, technology-forcing versus consultation with industry, and nonmarket approaches.[1] The Clean Air Act is an important example of command-and-control regulation affecting the auto industry. The Clean Air Act Amendments of 1970 and 1990 regulate both automobile tailpipe emissions and industrial plant air emissions. Technology-forcing strategies are widely applied in the Act, as illustrated by the requirements to use Best Available Control Technology for smoke-stack scrubbers; to reduce tailpipe emissions, prompting the use of catalytic converters; to ban leaded gasoline; to install on-board diagnostic systems to monitor vehicle emission controls; and to allow provisions for California and other states to mandate zero-emission vehicles. Such regulations have generally improved air quality in the U.S., however, it has come at a price. Additional compliance costs to industry from the 1990 Amendments alone have been estimated at $25 billion each year.[1]

The paint shop is the major source of emissions in an automobile assembly plant and is subject to extensive federal, state, and local environmental regulations. The following are the major federal regulations which affect the automotive paint facility: 1) the Clean Air Act Amendments of 1970 and 1990, which control the release of volatile organic compounds (VOCs) from paint solvents and hazardous air pollutants (HAPs); 2) the Clean Water Act Amendments of 1977, which regulate paint shop emissions to the water; 3) the Resource Conservation and Recovery Act of 1976 (RCRA), which controls solid waste and hazardous waste generated by the paint shop; 4) the Toxic Substances Control Act of 1976 (TSCA), which regulates the use and distribution of toxic chemicals used in painting processes; 5) the Occupational Safety and Health Act of 1970 (OSHA), which controls worker exposure to toxic substances; and finally, 6) the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), which threatens financial liability in the case of hazardous waste contamination at the site. These environmental regulations often require expensive end-of-pipe control technologies, extensive reporting, and costly waste treatment and disposal activities, all of which contribute to the high manufacturing costs of automotive painting.

Policy makers in both government and industry are becoming increasingly aware of the need for more flexible regulations which allow industry to remove pollution at its source by the most cost-effective manner. A sign of this trend may be found in Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and the Pollution Prevention Act of 1990. SARA Title III, also named the Emergency Planning and Community Right-to-Know Act (EPCRA), establishes a system for the public disclosure of toxic chemical releases by industrial site through Toxics Release Inventory (TRI) reporting. The Pollution Prevention Act extended TRI reporting to include the amounts of chemicals that are recycled, used for energy recovery and treated on-site. Although the reporting is extensive, the goal of these Acts is to protect the environment through open sharing of information about chemical releases and pollution prevention activities. These policies may be considered to be a shift away from command-and-control regulation, and the Environmental Protection Agency (EPA) believes that EPCRA "...is considered one of the most successful policy instruments ever created for improving environmental performance."[2]

Collaborative initiatives between industry, government, environmental groups, and public interest groups are becoming increasingly important in environmental protection. Examples of cooperative initiatives in the auto industry include the EPA Common Sense Initiative, EPA Waste Wi$e Program, EPA 33/50 Program, the American Automobile Manufacturers Association (AAMA) Automotive Pollution Prevention Project, the Department of Energy (DOE) Motor Challenge Program, the EPA/DOE

Climate Wise Program, and the United States Council for Automotive Research (USCAR) Partnership for a New Generation of Vehicles. Both collaborative programs and pollution prevention initiatives are important future trends in environmental policy for expected improvements in environmental performance and lower costs. The significance of pollution prevention is further illustrated in the following excerpt from the Pollution Prevention Act of 1990:

> The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.[3]

These examples in the U.S. automotive industry indicate increased efforts by both industry and government to move away from command-and-control environmental regulation toward initiatives involving information sharing, collaboration, and pollution prevention.

1.3 Brief History of Automotive Electrocoating

The electrocoat process, currently the only coating stage which contains lead, is just one step in the multi-stage automotive painting process. A typical automotive painting process consists of the following basic steps: 1) clean and rinse to remove dirt and oil from the auto body; 2) zinc phosphate rinse to prepare the surface metal for paint adhesion; 3) electrocoat primer for corrosion resistance; 4) sealer to prevent discoloration of the base coat by electrocoat pigments; 5) primer-surfacer to provide an even surface for the base coat; 6) base coat to provide the color finish; and 7) clear coat to create a glossy appearance. Many paint systems also include undercoating and stone-guard coating in certain areas to prevent chipping and subsequent corrosion. The main environmental issues confronting automotive painting include VOC releases from paint solvents, HAPs, and hazardous and nonhazardous waste disposal. Only the electrocoat process is investigated in this thesis to illustrate a pollution prevention opportunity to remove lead, a hazardous metal, from the painting operations.

Although the main purpose of the electrocoat primer is to inhibit corrosion of the metal substrate, e-coat also resists chipping of the paint film, provides adhesion for subsequent painting stages, and improves the overall finished appearance by reducing metal roughness.[4] This is achieved today through a paint-plating process in which the auto body is ground (negatively charged) and immersed into a tank of positively charged, water-thinned paint. This process is called cathodic electrocoating because the auto body becomes the cathode to which the paint is attracted and deposited. The typical cathodic electrocoat bath consists of an aqueous polymer, pigments, solvents, and deionized water.[5] The key to electrocoating is its throwing power, the ability of the paint to coat box sections or recessed areas of the auto body. By uniformly coating all surfaces of the car body, including complex geometries and sharp edges, corrosion resistance is greatly improved. After this deposition process in the dip tank, the auto body is conveyed through a closed-loop, multiple rinse process to remove the non-deposited paint solids, and finally, the body enters a curing oven where the electrocoat primer is cured to its final state.

The cathodic electrocoat process has evolved over the last forty years and is still evolving today. Research into electrodeposition paint first began in 1957 at the Ford Motor Company, and the first auto body tank was installed at the Wixom plant in 1963.[5] Before this time, automotive priming systems evolved from solvent-borne spraying primers, to solvent-based dipping primers, to water-borne dipping primers. The first electrodeposition system was an anodic process which achieved a major breakthrough by allowing high production output and providing coating protection to all body surfaces. Anodic electrodeposition also greatly reduced fire hazards and pollution from the earlier solvent-based systems. Cathodic electrodeposition systems, first used in the mid-1970's, transformed automotive priming. Some advantages of the cathodic process include improved corrosion performance, improved throwing power, improved adhesion, and inherent stability.[4] Cathodic electrocoating is the universal choice for automobile priming today, and 98% of all car bodies produced globally are electrocoated.[6]

As automotive priming evolves, environmental considerations are becoming increasingly important. The major evolutionary developments in electrocoating are often referred to as generations. First generation (1975-1977) cathodic electrocoats had high emissions from organic solvents and the heavy metals lead and chrome. The second generation (1978-1980) reduced VOC emissions by 50 to 70%. Third generation (1980-1982) electrocoats further reduced VOCs and reduced curing temperatures, and the fourth generation (1987-1991) provided a significant reduction in solvent emissions.[4] The fifth generation (1991) electrocoat paints improved throwing power without improving environmental performance, however. A sixth generation formulation, developed in 1994, was generally skipped by customers for a seventh generation product. Finally, the seventh generation (1995) electrocoats were developed which are HAPs-free and/or heavy-metal-free. Both the automotive original equipment manufacturers (OEM's) and the automotive parts and accessories (APA) manufacturers use cathodic epoxy-based electrocoats. The OEM's use a gray-colored formulation for auto bodies and are continuing to use the fourth and fifth generation electrocoats.[7] The APA manufacturers, however, use a black formulation and are changing to seventh generation, environmentally superior primers. These different e-coat choices between the OEM's and APA manufacturers are discussed in Chapter 4.

This overview of innovations in auto priming reflects the trends of environmental regulation in the auto industry. When the first generation cathodic electrocoats were being developed, environmental law in the U.S. was just gaining momentum. When the Clean Air Act and the 1990 Amendments were implemented, the electrocoat paint suppliers responded with low VOC paints. Today, electrocoat producers are developing low VOC, HAPs-free, and heavy-metal-free primers which may allow manufacturers to out-perform regulations and enter the realm of pollution prevention. One major paint supplier predicts the future of electrocoat paints in the following advertisement: "BASF anticipates the needs of the industry for environmentally friendly electrocoat paint products. While lower VOC and reduced emissions products have been the focus in the present, BASF Electrocoat has gone a step further and developed a lead-free formulation to meet the needs of the future."[8]

Chapter 2. Lead-Free Electrocoat in Automotive Priming

2.1 Product Formulation

Cathodic, epoxy ELPO paints used for auto body priming contain lead compounds in the pigment portion of the paint. The lead compounds aid in corrosion resistance and act as a curing catalyst.[9] The three main automotive paint suppliers have developed the following lead-free alternatives: BASF Cathoguard 310, DuPont Cormax IIIES, and PPG Enviroprime. One paint supplier explained that the paint resin was altered to improve corrosion resistance and the crosslinking agent was altered to improve the curing process, resulting in a lead-free product equivalent to the leaded electrocoat. Although there is practically no production experience with lead-free, auto body ELPO, the paint suppliers maintain that the lead-free version matches the process parameters and performance of electrocoats currently used by the OEM's.

2.2 Process Parameters

Due to the high capital investment in the dip tank and other equipment, it is important that new electrocoat paint formulations have similar process requirements to the current system. Table 2.1 compares typical leaded to lead-free operating parameters for cathodic, auto body electrodeposition. Conversations with an automotive electrocoat paint supplier revealed that under a full-scale, car body dip condition, lab results using lead-free electrocoat show similar operating parameters to conventional e-coat formulations. Although most parameters for lead-free are not expected to change, the lead-free pH of approximately 5.7 is slightly more acidic than the leaded electrocoat. Also, the optimal bake occurs after 20 minutes at 350 °F (177 °C); however, the curing time and temperature need not change from current practice.[9]

Table 2.1 Cathodic Electrodeposition Operating Parameters

Parameters	Typical Leaded Values[4]	Lead-Free Values[9]
Operating bath solids	20-25 % by wt	15-20 % by wt
Operating bath temperature	22-28 °C	No change
Applied voltage	250-300 V	No change
Deposition time	2-3 min	No change
pH at 27 °C	6-6.8	5.7
Effective curing time	20 min	No change
Effective curing temperature	160 °C	No change (177 °C)

At one time, there was a belief that lead-free ELPO would have a considerably lower pH resulting in increased corrosiveness to pumps and other equipment. This prompted the concern that switching to lead-free paint would necessitate changing applicable equipment to stainless steel and PVC, thereby increasing capital costs. The results of laboratory tests and the higher-than-expected actual pH of lead-free electrocoat support the industry conclusion that equipment changes are not necessary, although new and rebuilt paint shops are using stainless steel and PVC equipment for other durability issues.

Automotive parts suppliers have generally had more experience with lead-free electrocoats than the OEM's. A German parts supplier describes its experiences with a lead alternative in the following: "We worked out a process for converting the tank that consisted of gradually adding the unleaded product to the leaded product. Throughout the conversion phase, we observed no decline in quality or any other problems."[10] Based on paint and part suppliers' experience, there is no evidence that process changes are required to implement lead-free electrocoat paint into a new or existing auto body dip system.

2.3 Quality and Performance

The importance of electrocoat quality and performance cannot be overstated. One of the first aspects the customer notices about a finished vehicle is the paint job. The priming process is critical because it creates the primary surface to which all subsequent coatings adhere. Of equal importance, priming provides the most protection against corrosion. Electrocoat quality and performance problems may be very costly to automakers, both in repair costs and product liabilities. Any new electrocoat paint formulation must pass strict performance tests, and each U.S. automaker has developed its own electrocoat tests and specifications. Some important performance parameters include corrosion protection, throwing power, adhesion to substrate and subsequent coating layers, and film thickness. The major electrocoat paint suppliers maintain that the performance parameters will not change with the lead-free formulation, and several lead-free ELPO paints have passed the automakers' performance tests. There is no evidence that quality and performance will change with lead-free electrocoat.

2.4 Environmental Considerations: Hazard Assessment of Lead

With few process, performance, or quality changes expected, the greatest anticipated benefits of lead-free electrocoats are reduced health and environmental hazards. Lead is jointly ranked as the number one priority hazardous substance by the EPA and the Agency for Toxic Substances and Disease Registry (ATSDR).[11] Lead and lead compounds are SARA Title III chemicals and Pollution Prevention Act chemicals which must be monitored through TRI reporting. Lead and its compounds are also EPA 33/50 chemicals which had voluntary reduction goals of 33% by 1992 and 50% by 1995. Furthermore, the toxics are "Auto Project" chemicals. The Automotive Pollution Prevention Project focuses on reducing Great Lakes Persistent Toxics, such as lead, through pollution prevention. Finally, the heavy metal must be disposed of as hazardous waste under RCRA. Both environmental regulation and voluntary reduction initiatives identify lead as a priority toxic to be controlled. The human health and environmental concerns of lead will be discussed under the following hazard assessment topics: presence in the environment, toxicity, persistence, bioavailability, and potential to bioaccumulate and bioconcentrate.

Presence in the Environment

Presence in the environment is determined by measuring contaminant levels in water, sediments, animal tissue, or human tissue. Lead exists in water and soil in varying amounts depending on location. Lead particles have deposited in soil and water from flaking lead paint, incinerators, leaded gasoline, waste disposal, and certain industrial processes.[11] Reported soil lead levels range from less than 100 ppm to over 11,000 ppm, with less than 50 ppm being the natural level of lead in surface soils.[12] Lead is also found in wildlife, notably Great Lakes fish, and in the hair, urine, bone, teeth, breast milk, and blood of humans.[13] Furthermore, the current body burden of lead in the general population is two or three times greater than historical background levels.[11] This evidence indicates that lead has a high presence in the environment.

Toxicity

The Great Lakes Water Quality Agreement defines a toxic substance as a "substance which can cause death, disease, behavioral abnormalities, physiological or reproductive malfunctions or physical deformities in any organism or the offspring, or which can become poisonous after concentration in the food chain or in combination with other substances."[13] Lead is identified as a toxic chemical because it meets all of the above criteria, even death in extreme cases involving children.

Reproductive Toxicology: Lead effects on the reproductive system have been well documented through wildlife studies, animal laboratory experiments, and epidemiological studies of occupational exposure. There is a lack of knowledge, however, about the reproductive effects of chronic and low-level exposures. Human and animal studies show the following developmental effects of high-level, lead exposure: intrauterine growth retardation, altered gestational lengths, low birthweight, congenital deformities, and spontaneous abortions.[14] Human and animal studies also document the effects of lead on fertility. Female reproductive concerns include altered menstrual cycles and the suppression of certain hormones during menstruation. Fertility concerns for men include reduced sperm count, increased abnormal sperm, and altered pituitary and testicular functions.[13] Lead has therefore been shown to have an effect on human and animal reproductive health.

Immunotoxicity: Limited data from animal experiments and epidemiological studies of occupational exposure show heavy metals to be among the most important immunotoxic inorganic substances, even at low doses. Lead depresses antibodies in an organism and makes it more susceptible to infectious diseases. Lead may also enhance certain immune responses causing autoimmune and allergic reactions.[15] Finally, immunotoxicity may have the greatest effect on children, the elderly, and the ill.

Neurotoxicity: There is a high correlation between experimental and epidemiological studies documenting the intellectual and behavioral effects of lead exposure. Human exposure in utero and/or during childhood may cause neurotoxicity, even at low levels of lead exposure. Effects in children include lower IQ, deficits in abstract thinking, distractibility, inattention, hyperactivity, jitteriness, hypersensitivity, abnormal infant cry, increased reaction time, poor muscle tone, and abnormal reflexes.[13] Furthermore, at today's body burdens of lead, there is no threshold for intellectual damage to a developing organism exposed to lead.[13] Neurotoxic effects of lead have been the most extensively studied and documented of the various health risks.

Persistence

The Great Lakes Water Quality Agreement defines a persistent chemical as "any toxic substance with a half-life in water greater than eight weeks."[13] The half-life of lead in water is over 200 days (approximately 28 weeks).[16] Also, the half-life of lead in blood is 25 days, in soft tissue is 40 days, and in bone is 25 years.[11] Based on these findings, lead is considered highly persistent in the environment.

Bioavailability

Bioavailability is the extent to which organisms absorb a substance upon exposure. The main route of lead exposure is ingestion; therefore, most data regarding bioavailability examines lead absorption during digestion. Experiments using rats show that lead carbonate and lead salts are the most readily absorbed lead compounds in the rat kidney.[17] Metallic lead is also absorbed by the rat kidney, but at a lower rate. Lead metabolism differs greatly between adults and children, with children retaining 30 times the ingested dose of lead as adults.[18] Lead may also be absorbed by organisms through inhalation and dermal exposure. Regardless of how lead enters the body, after it enters the bloodstream, it moves throughout the body and is eventually stored in bone or soft tissue such as the kidneys and the nervous system.[19]

Bioaccumulation and Bioconcentration

Bioaccumulation is the process by which a substance concentrates in body tissue after digesting another organism exposed to the substance. Lead bioaccumulates in the aquatic food chain and becomes available to concentrate in the tissue of higher predators which feed on aquatic life. Lead therefore bioaccumulates in human tissue through the consumption of contaminated sport fish, for example.[20] Bioconcentration occurs when pollutants are directly absorbed from the environment, and the organism cannot eliminate the pollutant as fast as it enters the body. Bioconcentration does not include substances accumulated through the consumption of food. Over 95% of lead absorbed and retained by the body is stored in bone. Because lead stored in bone may remain for decades, bone accumulates significant concentrations of lead over time.[18] This evidence suggests that there is potential for lead bioaccumulation and bioconcentration in wildlife and in humans.

In summary of the human health and environmental implications of lead, the heavy metal has a significant presence in the environment and is considered toxic due to reproductive effects, neurotoxicity, immunotoxicity, and in extreme cases, death. Lead is also highly persistent in the environment and in organisms because it is nonbiodegradable and has a long half-life. Lead is readily bioavailable through ingestion, inhalation, and to a lesser degree, dermal exposure. Finally, lead is known to bioaccumulate and bioconcentrate in animals and humans. For these reasons lead is considered the number one priority hazardous substance by the EPA and ATSDR and one of eleven priority contaminants in the Great Lakes Basin of the U.S.

2.5 Environmental Considerations: Impacts of Electrocoating

Although the human health and environmental impacts of lead and lead compounds are well established, the impacts of the lead compounds in automotive electrocoating are less conclusive. Most of the documented human health impacts of lead concern ingestion of contaminated dust by inner-city children and occupational, high-level exposure. Also, most of the documented environmental impacts of lead concern bioaccumulation and bioconcentration in fish, birds, and other wildlife. Because the automobile electrocoating process is a closed-loop system during normal operation, there is little release to air or water. There is no worker interaction with the dip tank or rinses during normal operation, minimizing occupational exposure. In the event of overflow, accidental spill, or cleaning and maintenance of the system, there may be lead releases to water and occupational safety issues. If a manual sanding operation is implemented during rework, there is a concern that lead particles may be released into the air, creating an occupational safety issue. In general, however, the automobile paint shop does not pose a great risk for lead exposure to air or water, thus minimizing human health and environmental impacts.

Perhaps the greatest environmental concerns regarding lead and lead compounds in electrocoating pertain to waste disposal. The electrocoating process includes a filtration system to remove contaminants from the paint bath. The bag filters in the system must be periodically replaced to ensure proper filtration. Because the discarded filters are contaminated with lead from the paint bath, they must be handled and disposed of as hazardous waste under U.S. environmental regulations. On average, an automotive assembly plant may generate between ten to thirty tons of ELPO paint sludge and bag filter waste per year, depending on production volume and plant processes. This waste is typically sent to hazardous waste landfills; although less commonly, some plants choose to incinerate all or part of the wastes. In either event, landfilling and incineration are considered last-choice alternatives under the realm of pollution prevention discussed in Chapter 1.

Another important component of the ELPO waste stream concerns end-of-life vehicles. At the end of a vehicle's useful life, it will generally be taken to a shredder operation to recover the scrap steel and other valuable metals. First, the tires, radiator, gas tank, battery, air bags, and catalytic converter are removed to be recycled or disposed of separately. The rest of the vehicle is then shredded into small pieces which are magnetically separated to remove the ferrous scrap for recycling. Of the non-magnetic portion, 2-4% is copper, 1-2% is lead, 6-15% is zinc, 6-16% is iron, 20-25% is rubber and plastics, and 35-50% is glass, dirt, and dust.[21] More specifically, the shredder output is usually separated into the following three categories: 1) magnetic ferrous scrap, 2) non-magnetic, heavy scrap containing non-ferrous metals, and 3) light scrap (mostly polymers, fabrics, and glass) called auto shredder residue (ASR) or fluff.[22] ASR is currently the unrecyclable portion of the automobile, and it is gaining attention internationally, notably in Germany and Canada, for its potential environmental impacts. Increasing landfill costs and environmental concerns over the fate of ASR contaminates in landfills are two important issues in the shredder industry.[22]

Lead from automobile electrocoating operations may impact ASR. Laboratory analysis of ASR reveals a 0.28% average composition of lead.[22] There is controversy, however, regarding the amount of lead that actually leaches from landfills, causing an environmental concern. The following excerpt from a recent study by the Institute for Environmental Chemistry in Ottawa, Canada, illustrates some concerns of lead in ASR:

> "Of all trace metal contaminants in the environment, lead is probably the one which has been most widely studied. In the case of ASR it is also the metal which is of the greatest concern to the shredding operators. According to information obtained from GM Canada the following represent the largest usage of lead in new 1991 automobiles in decreasing order of importance: batteries, brake drum castings, connection wires, electronic devices, *ELPO coatings used as car body primers*, engine bearings, stabilizers in PVC plastic wiring, radiator solder, body solder and turncoat steel used in gas tanks, brake tubing, etc. Consequently it is not surprising to find relatively large quantities of lead in ASR samples..."[22](*Emphasis added*)

The assortment of different materials composing ASR, particularly lead and PCB's, makes it a target for classification as hazardous waste in some regions. For example, Quebec, Canada treats ASR as a hazardous waste due to high zinc and lead concentrations in the leachant.[23] While the largest source of lead on the automobile is the battery, batteries are removed and recycled before shredding; therefore, electrocoat primer is one of the four most important sources of lead in ASR, according to the excerpt.

Although the closed-loop system used in automotive electrocoating is considered highly efficient, low polluting, and safe, the main environmental concern is disposing of the lead waste. The ELPO lead waste stream includes any paint sludge waste generated during maintenance and cleaning, discarded bag filter waste, and lead waste in ASR at the end of the vehicle's useful life. The typical method of dealing with each of these wastes is landfilling or less commonly, incineration. Removing the lead in electrocoat paint through a pollution prevention initiative would greatly reduce or eliminate the toxicity of these waste streams.

Chapter 3. Total Cost Analysis of Lead-Free Electrocoating

3.1 Description of Total Cost Analysis

Total cost analysis (TCA), sometimes called total cost assessment, total cost accounting, or full cost accounting, is a financial tool which may be used by decision makers in industry to evaluate both the traditional costs and environmental costs of projects. TCA may be a particularly useful tool in evaluating pollution prevention projects by comparing the total cost impacts of a current process to a proposed, environmental process change. Conventional financial analyses and capital budgeting processes used in many businesses today may diminish the financial opportunities of pollution prevention projects.[24] Pollution prevention projects may be under-valued in a traditional analysis because they often involve indirect upstream and downstream changes to the process which are not usually included in the financial analysis, such as environmental compliance, waste management, and worker health care savings. Also, the benefits of pollution prevention may be difficult to quantify and are therefore usually excluded, such as avoided liability and green product sales. Finally, pollution prevention projects may not appear financially worthwhile in conventional analyses because their benefits may occur over longer time periods than normally used. TCA, however, allows pollution prevention projects to be evaluated on a more equal footing to other projects.[24, 25] Two theories of TCA structure are discussed in this section.

Paul E. Bailey, senior vice president of ICF Incorporated, a nationwide environmental consulting firm in Fairfax, Virginia, decomposes TCA into the following four levels of costs: usual capital and operating costs (Tier 0), hidden regulatory costs (Tier 1), contingent liability costs (Tier 2), and less tangible costs (Tier 3).[26]

Usual Costs (Tier 0): The usual costs include the capital and operating costs traditionally used in a financial analysis. Capital costs may include the costs of buildings, equipment, site preparation, and installation. Operating costs may include one-time costs such as start-up, permitting, and training, and recurring costs such as materials, labor, and utilities.[26]

Hidden Regulatory Costs (Tier 1): Hidden regulatory costs are the costs of regulatory compliance which are usually allocated to overhead accounts in conventional cost accounting. In TCA, these "hidden" costs are charged to the projects in which they are generated to provide more informed decision making. Regulatory costs may include notification, reporting, permitting, monitoring and testing, training, and inspection costs.[26] The first step in determining these costs is to identify the applicable environmental regulations affecting the project, such as the Clean Air Act, Clean Water Act, RCRA, CERCLA, SARA, TSCA, and OSHA. The second step is to estimate the compliance costs for each of the applicable regulations. With this method, previously hidden regulatory costs may be allocated to the projects under evaluation.

Contingent Liability Costs (Tier 2): Tier 2 costs include both the predictable penalties and fines for noncompliance and contingent liabilities which may result from unforeseen environmental risks. Contingent liabilities may include legal claims, awards, and settlements for remediation, personal injury, and property damage.[26] Contingent liabilities have become increasingly important to industry since the enactment of CERCLA and subsequent legislation. Paul Bailey states, "Future liability costs are strictly equal to zero if and only if a company generates *no* hazardous waste and releases no hazardous materials. There are four types of waste and materials management activities to which significant future liabilities can attach: 1) releases to air or surface water, 2) treatment or storage in tanks, 3) transportation, and 4) land disposal (on-site or off-site)."[26] Although liability costs are an important aspect of TCA and may be significant in amount, they are often subjective and difficult to quantify. Statistics on past liabilities and predictive modeling techniques may be used to estimate liability costs for TCA.

Less Tangible Costs (Tier 3): Less tangible costs, or less tangible benefits, are costs or savings resulting from changes in revenues due to customer acceptance, employee relations, and corporate image. As the name implies, these costs are difficult to quantify and are usually excluded in traditional analyses, although they may be significant to decision making. TCA attempts to include less tangible costs, whenever applicable, to better represent the benefits of pollution prevention.

In comparing a proposed pollution prevention project to current practices, Paul Bailey recommends performing TCA in separate stages. After evaluating the project with only Tier 0, usual costs, if the pollution prevention project does not meet financial goals, then Tier 1 should be conducted. In this way, effort is not wasted in collecting unneeded data. If the project does not meet financial goals after Tier 1, regulatory costs, Tier 2 may be performed. If there is low confidence in the future liability estimates used in Tier 2, the by-difference technique is suggested.[26] In the by-difference technique, the cost difference after Tier 1 between the pollution prevention project and current practices is identified and compared to the company's value for avoided liability. If the increased cost of pollution prevention is less than its savings in avoided liability, the project is cost-justified. Similarly, the by-difference technique may be used in Tier 3 to compare any increased costs of pollution prevention to the value of increased sales due to improved corporate image, for example. The need for by-difference techniques highlights the difficulty of quantifying all the significant costs in TCA. Furthermore, it illustrates the need for informed management decision making concurrent with corporate policy when conducting a financial analysis.

Alternatively, Allen White, director of the risk analysis group at the Tellus Institute in Boston, Massachusetts, defines total cost assessment by four elements: 1) cost inventory, 2) cost allocation, 3) time horizon, and 4) profitability indicators.[24]

Cost Inventory: The cost inventory identifies all costs and savings applicable to a pollution prevention project. This includes the capital and operating costs used in a conventional cost analysis as well as indirect and hidden costs, contingent costs, and less tangible benefits. In other words, the cost inventory identifies all of Bailey's Tier 0 through Tier 3 costs. TCA was not developed, however, to include the social costs of a project. Social costs may include health and ecological impacts of unregulated pollutants, habitat loss, or loss of biodiversity, for example. These costs are externalities to the company because under current law, the company has no financial obligations for such costs.[24] Ideas in this area are changing, and some companies may choose to internalize social costs; however, it is not standard practice to include social costs in TCA. Table 3.1 provides a detailed example of the costs and benefits which are included in Allen White's first TCA element, the cost inventory.

Table 3.1 Total Cost Assessment: Examples of Costs and Benefits[24]

Direct Costs

- Capital expenditures
  - buildings
  - equipment
  - utility connections
  - equipment installation
  - project engineering
- Operation and maintenance expenses/revenues
  - raw materials
  - labor
  - waste disposal
  - utilities: energy, water, sewerage
  - revenue from recovered material

Indirect or Hidden Costs

- Compliance costs
  - permitting
  - tracking
  - manifesting
  - waste handling
  - labeling
  - emergency preparedness
  - reporting
  - monitoring
  - training
  - recordkeeping
  - testing
  - medical surveillance
- Waste storage
- Operation of on-site pollution control equipment
- Raw materials costs linked to nonproduct output
- Environmental insurance (acute events, gradual impairment)

Liability Costs

- Penalties and fines
- Personal injury and property damage

Less Tangible Benefits

- Increased revenue from enhanced product quality
- Increased revenue from increased share of green product markets
- Reduced worker compensation and absenteeism costs from improved employee health
- Increased productivity from improved employee relations
- Reduced staff burdens in dealing with community concerns

Cost Allocation: After the costs are identified, it is important to allocate them to the proper processes in the project. Traditional cost accounting may lump certain costs into overhead accounts, inhibiting rational decision making regarding the cost impacts of some processes and opportunities for pollution prevention. The goals of cost allocation should be to associate costs with the processes that generated them and to track the costs in a manner which reflects how they are incurred.[24]

Time Horizon: Conventional financial analyses may use a two to five year time horizon to evaluate projects due to the desire for a quick payback on investment. This time frame may, however, disadvantage pollution prevention projects which often provide savings in the long term. In TCA, ten to fifteen years or more is a preferred time horizon to capture more of the costs and benefits associated with pollution prevention.[24]

Financial Indicators: According to Allen White et al, "Financial indicators for pollution prevention projects should meet two criteria: 1) a capacity to incorporate all cash flows (positive and negative) over the life of the project; and 2) a capacity to integrate the time value of money through appropriate discounting of future cash flows."[24] Net Present Value (NPV), Internal Rate of Return (IRR), and the Profitability Index (PI) are three indicators that meet the criteria. Payback is a very common financial indicator; however, it does not incorporate future cash flows beyond the payback period. The payback period is the expected time in which a project's initial investment is recovered. Although useful for quick, preliminary assessments, payback is not a recommended financial indicator for pollution prevention projects because it does not account for long-term cash flows.[24]

Net Present Value, Internal Rate of Return, and the Profitability Index incorporate discounted cash flows over the life of the project. NPV is the present value of all future cash flows, discounted by a predetermined discount rate, minus the initial investment for the project. If the NPV is a positive number, the project is worthwhile, based on the time value of money represented by the discount rate; if the NPV is negative, the project is not worthwhile at the chosen discount rate. NPV is very sensitive to the chosen level of discount rate, particularly in longer-term (10 to 20 year) projects.[27] The calculation for IRR is essentially the same as for NPV; however, in calculating IRR, NPV is assumed to be zero, and the rate of return of the project is calculated. If the calculated rate of return is greater than the chosen discount rate, the project is worthwhile. Finally, the PI is the present value of all future cash inflows divided by the present value of all future cash outflows. A PI greater than 1.0 indicates that the project is worthwhile. Often, a financial analysis will include more than one financial indicator to convey information to decision makers because each method has its own unique advantages, disadvantages, and biases. Businesses generally use IRR and/or payback period in project analysis.[27]

Because a project financial analysis may be very sensitive to the discount rate, the choice of discount rate is discussed here in greater detail. The discount rate represents the change in value between money now and money later based on the possibility of productive use of the money. The discount rate is often thought of as a firm's opportunity cost of capital because if the firm did not invest in the project under consideration, it could invest it elsewhere. Therefore, the discount rate for a project should reflect the return the firm could earn on another investment of equal risk.[28] According to Professor Richard de Neufville of the Technology and Policy Program at the Massachusetts

Institute of Technology. "The choice of the discount rate is the single most critical element in any evaluation of benefits and cost over time. Relatively small changes in the discount rate can make a significant difference in whether a project appears desirable or not. The general rule is that higher discount rates make projects look less attractive."[27] The choice of discount rate may also determine the type of technology used in a project because lower discount rates favor capital-intensive technologies. Since the choice of discount rate is imprecise, it often becomes a controversial and political issue with proponents of a particular project or technology arguing for a discount rate that supports their desired outcome.[27]

Often companies will determine a corporate discount rate to evaluate all projects and avoid such internal conflicts. Manufacturing firms generally use discount rates of approximately 15%, while lower risk industries such as banks and regulated firms use discount rates closer to 10%.[27] Although potentially easier to manage, the use of corporate discount rates may bias certain projects. According to financial theory, lower risk projects should have lower discount rates, and higher risk projects should have higher discount rates. "Unless all projects in the corporation are of the same risk, choosing the same discount rate for all projects is incorrect."[29] In summary, the discount rate is an important concept in project financial analysis, and perhaps even more important in the total cost analysis of pollution prevention projects due to their long-term benefits. Because the chosen discount rate may be imprecise and may have a significant impact on the evaluation, it is important to include a sensitivity analysis of the discount rate in most project financial analyses.

3.2 Total Costs of Lead-Free Electrocoating

As an employee of General Motors Corporation and summer intern to the Environmental and Energy, Policies and Programs department at corporate headquarters, the author had the opportunity to help initiate a total cost analysis comparing the current auto body electrocoat process to a proposed lead-free process at one automotive assembly plant. The Tellus Institute of Boston, Massachusetts was consulted as experts in environmental cost accounting. While the Tellus Institute's analysis provided a basis for data collection, the analysis presented in this thesis attempts to provide a more general case, applicable to a typical auto assembly plant. Whenever possible, data for this analysis was gathered from the automotive industry as a whole, other automakers, and automotive paint suppliers. In particular, an automotive painting cost model developed by the Materials Systems Laboratory at the Massachusetts Institute of Technology (MIT) was used for much of this analysis.

The analysis presented in this section incorporates the ideas previously presented by both Bailey and White regarding the structure of TCA for pollution prevention projects. White's four TCA elements, cost inventory, cost allocation, time frame, and cost indicators, provide the main structure for the lead-free electrocoat TCA. Because Bailey's four tiers of costs closely resemble White's four cost categories in the cost inventory, Bailey's cost tiers are used in this analysis to create the cost inventory stage. The TCA presented here is therefore a of hybrid of both TCA theories.

Cost Inventory

Because the pollution prevention project is compared to the current practice, the differential between costs and savings is used in this analysis instead of the actual costs and savings for each case. Therefore, any aspect of the process that does not change in switching to lead-free electrocoat is not included in this analysis. The costs which do impact the lead-free project will be discussed in the context of usual costs, regulatory costs, liability costs, and less tangible costs.

Usual Costs (Tier 0): Usual costs include both investments and operating costs. All costs included in this analysis are based on the assumption that the lead-free project is installed in a new paint shop that has not been previously contaminated by a leaded product, and the new paint shop has an expected life of twenty years. The usual cost impacts for lead-free electrocoat are shown in Table 3.2 below.

Table 3.2 Differential Usual Costs of Lead-Free Electrocoat

Cost Category	Description	Cost/Saving - / +	Time Incurred
Investment	Start-up paint performance tests	-	year 0
	Initial paint inventory	-	year 0
Operating	Paint cost	-	years 1-20

The first cost results from start-up paint performance tests usually required by an automaker when a new paint product is introduced to a plant. The initial paint inventory cost includes the initial paint quantity for the dip tank and extra paint inventory stored at the plant. Although a new paint shop would need such inventory regardless of the type of electrocoat, the lead-free paint is estimated to cost 10-12% more than the current paint, according to one paint supplier. Also, the operating cost impact results from the increased price of the lead-free paint. The operating cost increase of lead-free paint dominates the Tier 0 costs. Only costs and no savings are recorded in the Tier 0 cost inventory; therefore, the Tier 1 cost stage must be pursued.

Regulatory Costs (Tier 1): Regulatory costs in the TCA may include one-time costs and recurring costs. The regulations generating these costs may be RCRA, OSHA, SARA Title III, and the Clean Water Act. The regulatory cost impacts of lead-free electrocoat are shown in Table 3.3 below.

Table 3.3 Differential Regulatory Costs of Lead-Free Electrocoat

Cost Category	Description	Cost/Saving -/+	Time Incurred
Decommissioning	Demolition & cleaning of equip.	+	year 20
(One-time costs)	Disposal of equipment	+	year 20
Recurring	Filter waste & sludge disposal	+	years 1-20
	OSHA worker training	+	years 1-20
	TRI reporting	+	years 1-20
	Wastewater treatment	+	years 1-20
	Worker lead testing	+	years 1-20

Decommissioning occurs at the end of the paint shop's useful life when the equipment is dismantled, cleaned, and disposed or reused. Decommissioning of lead-free equipment is a savings because the lead-free project eliminates the extensive environmental controls required in the dismantling and cleaning of lead-contaminated equipment. Also, the lead-free equipment may be sold as scrap, whereas the lead-contaminated equipment is charged a fee by smelters. The dominant recurring savings are the lower disposal costs for filters in the lead-free case. Without lead, the filters may be disposed of as nonhazardous waste which is less expensive to handle, transport, and landfill than hazardous waste. The same is also true for paint sludge; however, only minor amounts of paint sludge are usually disposed. The OSHA training savings results from the elimination of mandatory training for lead handlers, and the TRI reporting savings results from elimination of lead and lead compound reports and monitoring. Some plants may save with less wastewater treatment costs due to lower lead content in the wastewater, and some plants may save on the elimination of mandatory blood lead testing for employees exposed to lead. Although Tier 1, regulatory costs, are all savings for the pollution prevention project, the savings may be small compared to the higher paint costs in Tier 0. Also, while the decommissioning savings may be significant, they do not occur until year 20, and discounting will result in the decommissioning savings having very little effect on the analysis. It may therefore be necessary to consider Tier 2, liability costs.

Liability Costs (Tier 2): Liability costs include fines and penalties for noncompliance as well as contingent liability costs which are often less certain. Table 3.4 summarizes potential liability cost savings resulting from the pollution prevention project.

Table 3.4 Differential Potential Liability Cost Savings of Lead-Free Electrocoat

Cost Category	Potential Savings	Time Incurred
Fines/Penalties	OSHA noncompliance	years 1-20
	RCRA noncompliance	years 1-20
	Clean Water Act noncompliance	years 1-20
	SARA Title III noncompliance	years 1-20
	Pollution Prevention Act noncompliance	years 1-20
Contingent liability	Personal injury - worker health	years 1-20
	Spills or leaks - CERCLA	years 1-20
	Landfill liability (filters & sludge) - CERCLA	years 1-20
	Landfill liability (ASR) - CERCLA, equivalent laws in other nations	years 1-20

Although automakers work diligently to avoid environmental fines and penalties, and the ELPO system has not historically been a compliance problem, lead in the process creates a risk for noncompliance. Even though the risk may be very slight, the cost of noncompliance may be considered a potential liability in the TCA. Likewise, the probability of personal injury to workers may be very small due to the closed-loop electrocoat system and other precautions; however some liability cost may exist, and this cost may be included in the analysis. Furthermore, the ELPO system has not been involved in CERCLA issues; however, as Paul Bailey emphasized, any release, treatment, storage, transportation, or land disposal of a hazardous material necessarily means that contingent liability costs are not equal to zero.

Two features that the contingent liabilities of the electrocoat system have in common are low probability of occurrence and potentially serious impact upon occurrence. The low probability of occurrence results from historical trends of proper containment and successful management of the hazardous material, and the potentially serious impact results from the human health and environmental hazards discussed in Chapter 2. Low occurrence, high impact risks may be very difficult to quantify and effectively manage due to differences in risk perception. Because a problem is not expected to occur, it may be perceived to be a very low risk; however, potential higher order impacts may result in greater liability than anticipated. The following excerpt from *Environment, Science & Technology* highlights further issues in risk management:

> "Far more complex risk management situations arise, for example, in groundwater contamination, in the disposal of hazardous wastes, or in the cleanup of abandoned waste disposal sites. These kinds of cases are not only technically complex, involving multiple exposures, cross-media pollution problems, and the assessment of ecological damage, but they can also involve sociopolitical, ethical, judicial, and legal factors. Such factors include the public's perceptions of risk; the interests of businesses, industrial organizations, and federal, state, and local governments; the interests of special neighborhood or local organizations and public interest groups; the effects of court decisions; and the possibility of litigation by one or more parties. If litigation occurs, it makes the task of risk management far more difficult, introducing delays and the possibility of additional financial risks - up to billions of dollars - into the process; these risks must also be assessed and taken into account."[30]

This excerpt supports assigning a liability cost to the current ELPO system of some value greater than zero. The actual value is very difficult to quantify; therefore, the by-difference method is used in this TCA to compare any cost increases of the pollution prevention project after Tier 0 and Tier 1 to potential liability cost savings.

Less Tangible Costs (Tier 3): Less tangible costs or less tangible benefits of a pollution prevention project in TCA include increased revenues which are often difficult to quantify and are often generated outside the process. Table 3.5 below lists some potential, less tangible benefits of lead-free electrocoat.

Table 3.5 Differential Potential Less Tangible Benefits of Lead-Free Electrocoat

Potential Savings	Time Incurred
Increased revenues from green product sales, particularly in Europe	years 1-20
Increased sales from improved company image	years 1-20
Increased sales from improved employee and community relations	years 1-20

Such benefits are very unpredictable in this case; therefore, the by-difference technique is again used to compare any Tier 0 and Tier 1 cost increases of the pollution prevention project to expectations of less tangible benefits.

In summary of the cost inventory stage of the TCA, only costs and no savings are recorded for Tier 0, usual costs. The increased price of lead-free electrocoat paint dominates this category of costs. Conversely, only savings and no costs are recorded for Tier 1, regulatory costs. The cost savings of disposing a nonhazardous waste is the dominant recurring savings, and although decommissioning cost savings may be significant, discounting results in decommissioning having little impact on the analysis. Finally, Tier 2 and Tier 3 benefits are very difficult to quantify due to lack of historical data or precedence. The by-difference method is therefore used in the next section to incorporate the liability and less tangible benefits of the pollution prevention project.

Cost Allocation

In conducting the TCA, the costs were identified in various accounts and allocated to the operations under evaluation. This involved soliciting information from such diverse departments as paint shop manufacturing, paint engineering, environmental engineering, waste management, facilities, and medical. This cost gathering and allocation stage constituted the greatest time and effort expended in the TCA process.

Time Horizon

The time horizon of the TCA is the expected life of the project. In the lead-free electrocoat case, it is assumed that the project is implemented in a new or rebuilt paint shop with an expected life of twenty years. The TCA time horizon is therefore twenty years.

Financial Indicators

The financial indicators which are discussed in the next section include Net Present Value, Internal Rate of Return, and payback period. These indicators where chosen due to their use in the industry. A discount rate of 15%, including inflation, was used in the Tellus portion of the analysis, which falls within the range of standard discount rates used in the industry.

3.3 Total Cost Analysis Results and Sensitivities

This financial analysis of the lead-free electrocoat project incorporates general results from the Tellus Institute analysis and results from MIT's Materials Systems Laboratory (MSL) automotive painting cost model, and it considers liability costs and less tangible benefits. Taken as a whole, these separate analyses create an important source of information for decision makers evaluating the pollution prevention project.

Tellus Institute Analysis

The goal of the Tellus analysis was to create a total cost assessment comparing the lead-free ELPO process to the current process. Research into historical liability data on the electrocoat process resulted in very little evidence of past liabilities from employee injury, accidental spills, or CERCLA. Therefore, liability costs (Tier 2) were not included in the Tellus analysis. Furthermore, less tangible benefits (Tier 3) were not included in the Tellus analysis, presumably due to difficulty quantifying such benefits and uncertainty that such benefits exist. The analysis considers only the usual costs (Tier 0) and regulatory costs (Tier 1) shown in Table 3.2 and Table 3.3, respectively. The Tellus analysis reports these costs as cash inflows and cash outflows in each given year for the twenty years of the project, incorporating tax considerations and discounting. The result is a thorough financial analysis of Tier 0 and Tier 1 costs.

The Tellus analysis concludes that the pollution prevention project is not financially worthwhile. The higher price of the lead-free electrocoat paint dominates the analysis, resulting in a financial loss relative to the lead process each year, before and after discounting. The undiscounted loss each year is several hundred thousand dollars, and the discounted, net loss over the twenty years is a couple million dollars. The Tellus Institute conducted a second analysis examining the effect of a possible ban on vehicle exports containing leaded paints to Europe. In the case of such a ban, the pollution prevention project is financially worthwhile. The lost export revenues from not changing to lead-free electrocoat more than compensates for the higher paint costs of the change. In this case, the NPV is positive, the IRR is greater than the 15% discount rate, and the payback period is approximately five years. In summary, the Tellus analysis of Tier 0 and Tier 1 costs shows that the lead-free electrocoat project is not financially worthwhile under the current situation. If sales are restricted due to lead content, however, the project may be profitable.

MSL Cost Model

The MSL cost model was developed specifically for the automotive painting process to determine average annual paint shop costs. It incorporates the cost of capital, operating costs, and many regulatory compliance and disposal costs. The model does not include year by year cash flows or discounted cash flows; its aim is to evaluate the average yearly costs of carrying and operating an automotive paint shop. The MSL cost model is used in this analysis to compare the average annual electrocoat costs of different inputs and to perform sensitivity analyses of these inputs. To correlate results with the Tellus analysis, the assumptions and inputs of the Tellus analysis were used in the MSL cost model. The electrocoat portion of the model was also updated to include all the Tier 1 regulatory costs previously identified in this analysis. The average annual cost differential of the lead-free electrocoat project, determined in the MSL cost model, therefore reflects the pre-tax, undiscounted results of the Tellus analysis.

To apply these results to the automotive industry over time, the chosen inputs may be changed to reflect differences between automakers, differences between paint suppliers, changes in regulation, and changes in prices and costs over time. The most likely inputs to change are the lead-free paint price, waste disposal costs, and the amount of waste disposed.

Lead-Free Paint Price Sensitivity: According to one paint supplier, the lead-free paint currently has a price premium because it costs more to produce, and the premium helps suppliers recuperate the research and development costs of the lead-free formulation. The future lead-free paint price may drop relative to the leaded formulation for several reasons. First, the price may fall after R&D investments have been recuperated. Second, if more automotive plants demand lead-free, the automakers may exert buyer power over the suppliers to reduce the price. Finally, if more plants switch to lead-free, paint suppliers may realize economies of scale and pass on the cost savings to their customers. In evaluating the pollution prevention project, it is important to understand how changes in paint prices affect the total annual electrocoat costs of the lead and lead-free processes.

A sensitivity analysis of total annual electrocoat costs to paint price was therefore conducted, and Figure 3.1 presents the results of this analysis. The current leaded process is used as the base case, and the data points are expressed as unitless values in reference to the lead values. Therefore, the current lead paint price is normalized, and the corresponding annual lead electrocoat costs are also normalized. Based on the Tellus inputs, the lead-free paint price is approximately 9% higher than lead paint, and as shown on the y-axis, this results in about a 4% increase in overall electrocoat costs. The total costs of the electrocoat process are therefore quite sensitive to the paint price. Also, at any given paint price, the current lead process costs slightly more than the lead-free, pollution prevention process. With the 9% price premium, however, the lead-free project costs about 4% more annually.

A break-even analysis was also conducted to determine the break-even price of lead-free electrocoat paint. Any price lower than the break-even price results in lower total electrocoat costs for the pollution prevention project. Again the current lead process is the base case, and the lead paint price and lead annual electrocoat costs are normalized. Figure 3.2 shows that the 9% price increase of lead-free is well above the break-even point, and a premium of about 0.3% or less results in lower annual electrocoat costs for the lead-free project versus the current process.

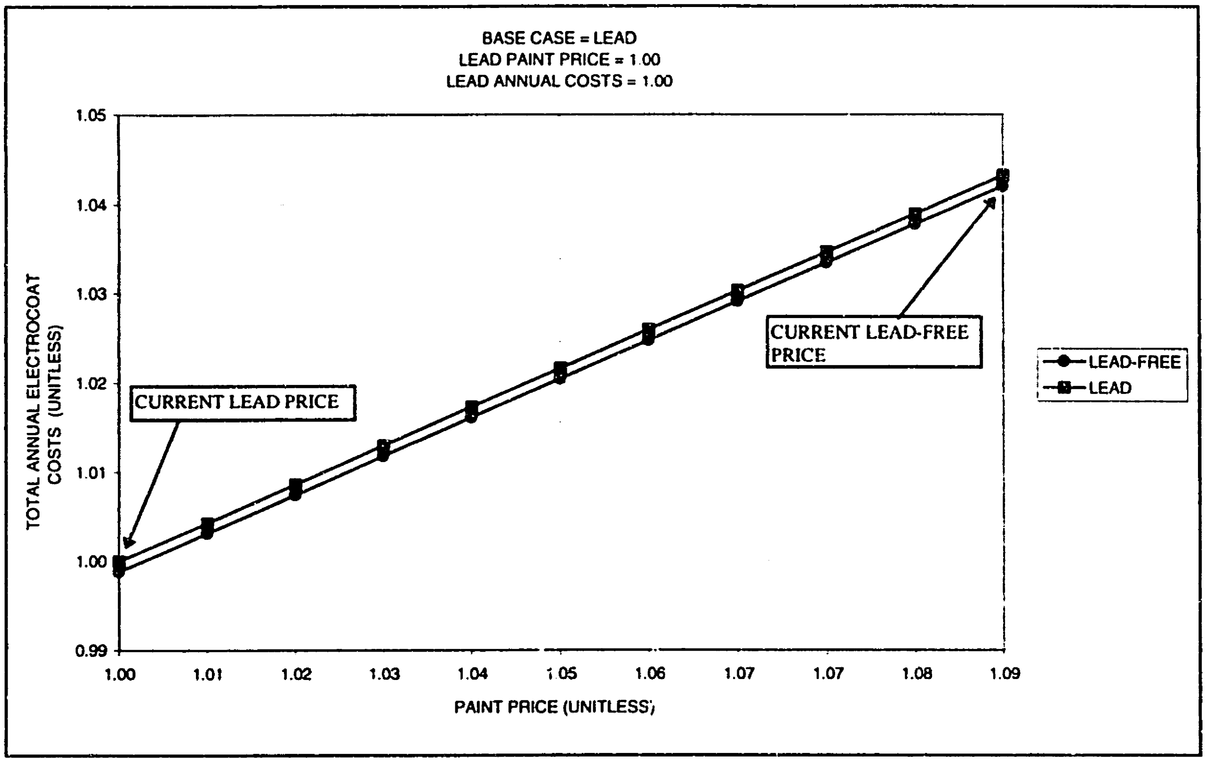

Figure 3.1 Sensitivity Analysis of Annual Electrocoat Costs to Paint Price

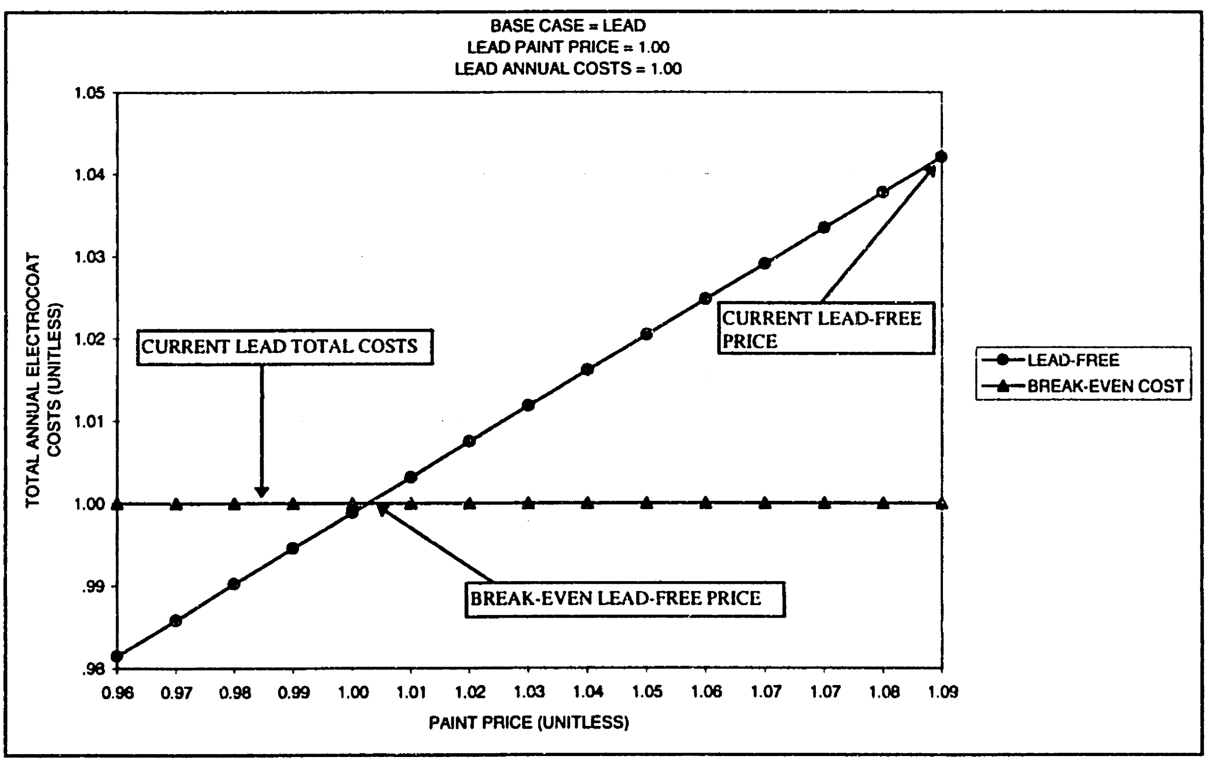

Figure 3.2 Break-Even Lead-Free Paint Price

Waste Disposal Cost Sensitivity: Waste disposal costs may vary for several reasons. Contracts with waste disposal companies may change from one automaker to another, and direct government regulation, threat of liability, and/or public opposition to new waste sites may increase costs in the future. The sensitivity analysis illustrated in Figure 3.3, however, shows that annual electrocoat costs are not sensitive to waste disposal costs. A doubling of the hazardous waste disposal costs for the lead process results in almost no impact on total electrocoat costs. At any given disposal cost, the lead-free project is approximately 4% more costly than the current lead process. The break-even analysis in Figure 3.4 shows that with everything else held constant, the hazardous waste disposal costs for the lead process must be almost 50 times the current disposal costs for the lead process to be more costly than the lead-free.

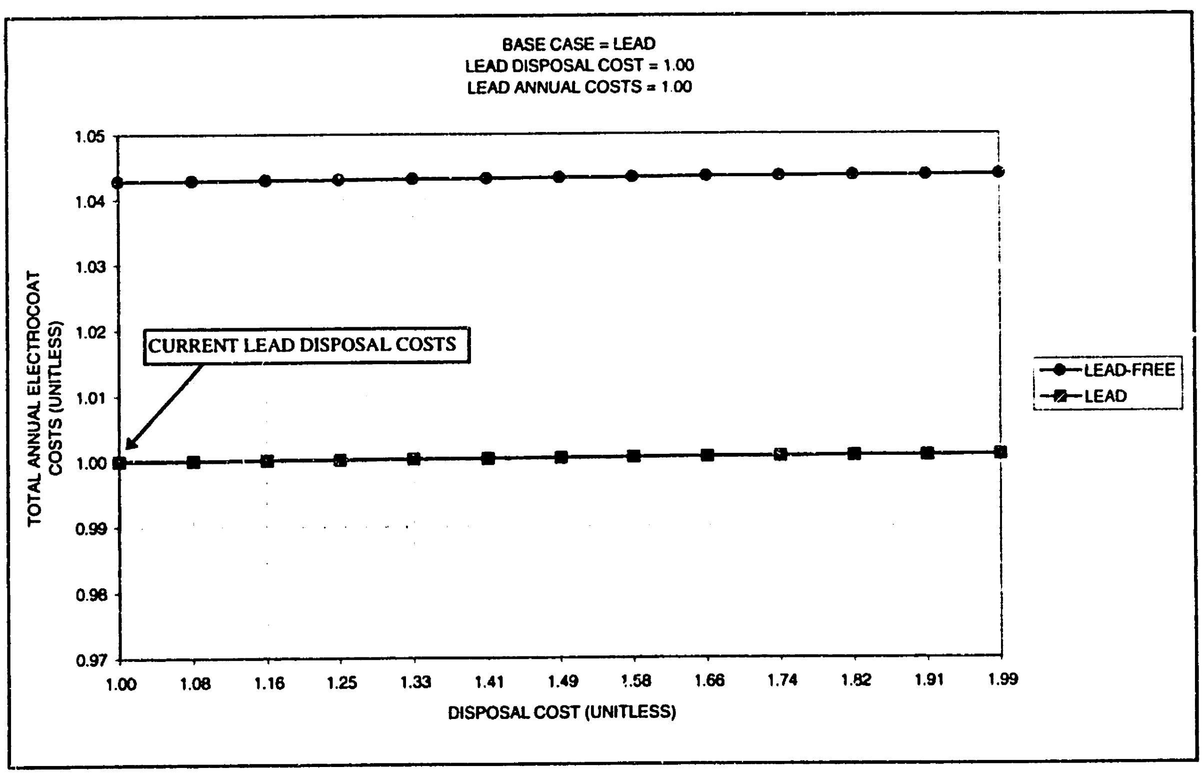

Figure 3.3 Sensitivity Analysis of Annual Electrocoat Costs to Waste Disposal Costs

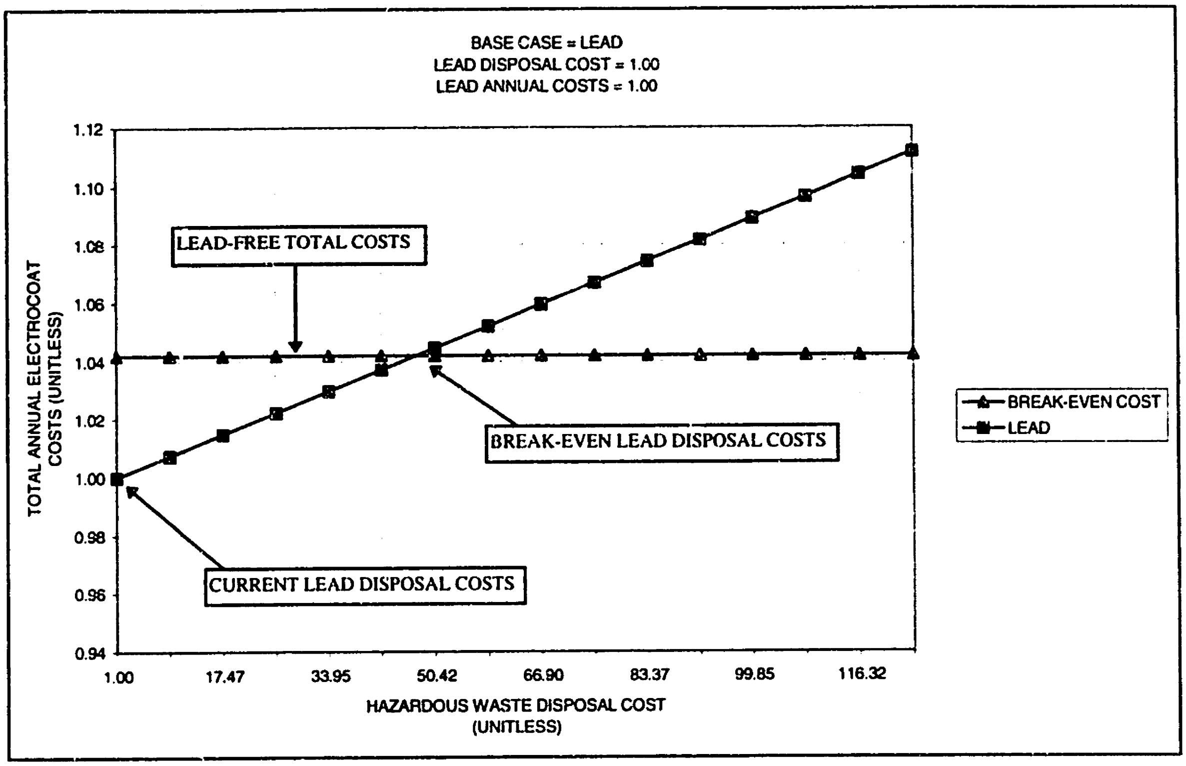

Figure 3.4 Break-Even Hazardous Waste Disposal Cost

Amount of Waste Disposed: The amount of waste generated and disposed per vehicle, mostly filter waste, may also change due to plant practices, technological innovations, and/or process changes. Figure 3.5, however, shows that annual electrocoat costs are not very sensitive to the amount of filter waste. Tripling the waste has almost no effect on the lead-free annual costs and only a slight effect on the leaded annual costs. Although the amount of waste generated in both processes is expected to be the same, any waste generated in the current lead process must be disposed of as hazardous waste, thus incurring higher costs than the nonhazardous lead-free waste. Again, the lead-free process is about 4% more costly than the lead process. The break-even analysis illustrated in Figure 3.6 shows that the amount of filter waste would have to increase almost 50 times for the current lead process to be more costly than the proposed lead-free process.

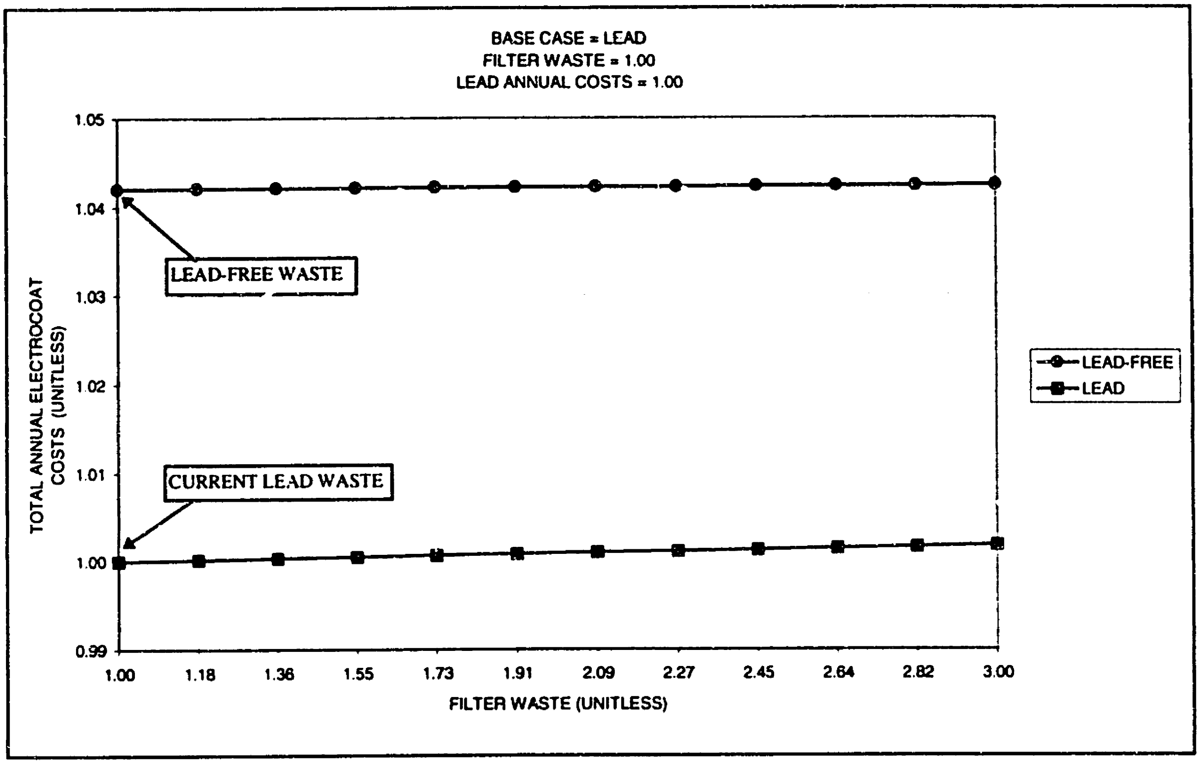

Figure 3.5 Sensitivity Analysis of Annual Electrocoat Costs to Filter Waste

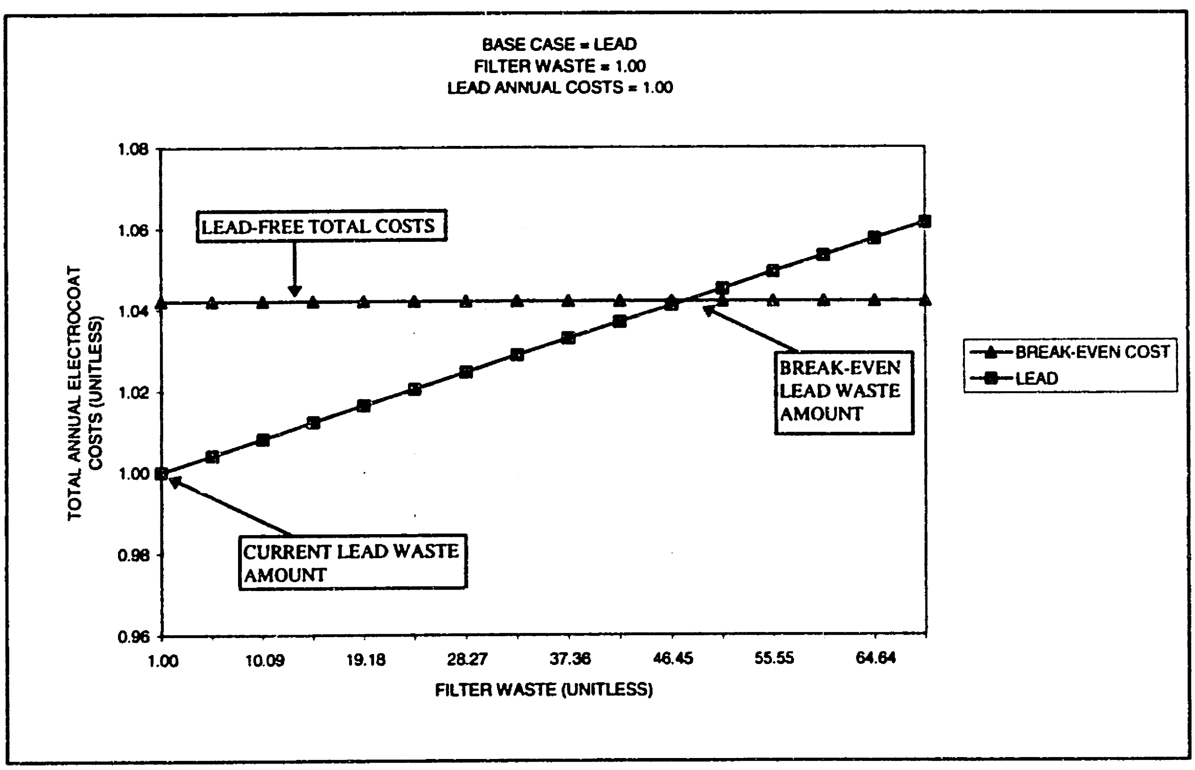

Figure 3.6 Break-Even Amount of Filter Waste

To summarize the results from the MSL cost model, the model may be used to represent the usual and regulatory average annual costs of the electrocoat process. The model indicates that the lead-free, pollution prevention project is approximately 4% more costly per year than the current lead process. This result is sensitive to the lead-free paint price. If the lead-free paint price is about 0.3% more than the lead paint price instead of 9% more, the conclusion changes, and the lead process is more costly. The result is not very sensitive to waste disposal costs or the amount of waste disposed. These inputs would have to increase 50 times to change the conclusion that lead-free is more costly. Finally, these results are based only on Tier 0 and Tier 1 costs and have not incorporated liability costs and less tangible costs.

Liability and Less Tangible Costs

Although the liability and less tangible costs of the current lead electrocoat system are not strictly equal to zero, the Tier 2 and Tier 3 benefits of implementing the pollution prevention, lead-free system may be subjective and difficult to quantify. The by-difference method is therefore used to incorporate liability and less tangible benefits into the TCA. Both the Tellus analysis and the MSL cost model report an annual cost increase of several hundred thousand dollars for the lead-free project, and the Tellus analysis shows a discounted increase of a couple million dollars over the twenty years. At this point in the TCA, the decision maker evaluating the pollution prevention project must ask, "Are the expected savings from liability benefits and less tangible benefits enough to offset the cost increase of the pollution prevention project?" If the answer is yes, the liability and less tangible benefits are expected to result in a savings of at least a couple million dollars over the next twenty years, then the lead-free project is financially worthwhile. Of course, if the answer is no, the project is not financially worthwhile, and other projects may be pursued instead.

The valuation of Tier 2 and Tier 3, liability and less tangible benefits, may differ from one company to another. Differences in company size, structure, culture, financial stability, and differences in risk management may influence how the decision maker values the savings from reduced liability and less tangible benefits. Although this TCA does not provide a single right answer, it does provide important information to assist the decision maker in making a choice which is financially sound for his or her company. By including all significant costs and benefits of the project over time, the TCA gives the decision maker a more complete picture of the financial impacts of the project, beyond the capital and operating costs traditionally considered. The TCA may also capture more of the financial benefits of the pollution prevention project usually missed in a conventional financial analysis, such as regulatory and compliance costs, liability costs, and less tangible benefits. In summary, TCA cannot replace decision making; it can only assist and improve decision making by providing more complete information than conventional analyses. An answer to the lead-free question is therefore not provided; however, the total cost analysis presented here shows that the price of the lead-free paint is a pivotal input, and the estimation of liability benefits and less tangible benefits may determine the financial feasibility of the lead-free electrocoat process.

Chapter 4. Strategic Considerations of Lead-Free Electrocoating

The pollution prevention project involving lead-free electrocoat may be evaluated on a level higher than total cost analysis. TCA is an important tool used to provide financial information for project evaluation; however, the strategic significance of a new technology may also be an important consideration in the decision-making process. To examine the strategic importance of lead-free electrocoat, the following topics are discussed: lead-free electrocoat use in the industry, impact of future regulations, and corporate environmental policy.

4.1 Lead-Free Electrocoat Use in the Industry

Use Among Automakers

An examination of the current uses of lead-free electrocoat among automakers may provide insight into the significance of this pollution prevention project as a competitive advantage. Chrysler Corporation is purported to be the first automaker to fully implement lead-free electrocoat in a North American vehicle assembly plant. In February 1997, during the writing of this thesis, the new, lead-free ELPO system became operational at Chrysler's Newark, Delaware assembly plant. During a telephone conversation with a Chrysler materials engineer, some understanding was gained about why the automaker decided to implement lead-free electrocoat. Originally, pressure from the federal government to remove the lead in the electrocoat system prompted Chrysler's interest in lead-free electrocoat paints. Upper management in the environmental department at Chrysler supported switching to a lead-free paint formulation upon technical approval. According to the Chrysler engineer, some reasons for this desire to switch may have been to exhibit good faith in dealing with the government and to be proactive in addressing environmental concerns. The final decision was not made, however, without considering the cost impacts of the change. A total cost analysis was conducted by the environmental department at Chrysler, and it showed a positive return for the lead-free system. Although the details of the TCA were not disclosed, liability costs were substantially valued in the analysis. Finally, the decision to change to lead-free was initiated at the corporate level through an environmental executive, and the engineering department for paint has been concentrating on such environmental improvements for the last five years.

By implementing lead-free electrocoat early, an automaker may have some degree of competitive advantage. The automaker may gain favor with environmental agencies in the government, allowing for more cooperative relations in the future. The automaker may also prove to the government that the technology is feasible, and the government may therefore regulate other automakers, who may be less prepared to change, into adopting the new technology. Finally, the automaker who implements early may enjoy competitive advantage in the marketplace. Good public relations regarding the timely implementation of a pollution prevention project may translate into increased overall sales, and although less likely, sales of the product line with lead-free electrocoat may increase due to "green" buyer consciousness. Perhaps most importantly, products manufactured today with lead-free electrocoats may avoid future sales restrictions due to environmental regulations or bans. It is therefore conceivable that an automaker may strategically implement an environmental technology, such as lead-free electrocoat, early to gain some degree of competitive advantage.

Use Among Automotive Parts Manufacturers

As previously stated, the automotive parts and accessories manufacturers are largely changing to lead-free electrocoat systems. However, only one automobile assembly plant has made the change. Since the lead-free paint formulation for automotive parts has a price increase similar to the auto body lead-free paint, cost savings does not initially appear to be the motive for the change. It is therefore important to examine possible strategic issues accounting for this lead-free trend among suppliers and not automakers. One explanation investigated was that the OEM's were demanding that the suppliers make the change for environmental reasons; however, this does not appear to be the case. According to one APA supplier, Metokote Corporation, "One of our biggest challenges was to get approval from OEM's and other customers to change the first generation cathodic epoxy tanks to the newer, lead- and chrome-free generations."[7] Similar experiences among other suppliers show that the APA manufacturers generally pressured the automakers to approve the lead-free paints. Another possibility for the lead-free trend among suppliers may be regulatory compliance issues. Because parts suppliers operate on a smaller scale, they may have fewer resources to devote to environmental compliance and reporting, waste management, and capital-intensive, on-site treatment facilities. Without the treatment facilities, suppliers may be more likely to expel wastewater directly into municipal treatment systems, subject to strict emissions limits. Furthermore, the potential worker health and environmental liabilities associated with the use of a hazardous substance may be greater than a parts manufacturer can financially withstand. Regulatory compliance and future liabilities may therefore have a greater impact on parts suppliers than automakers, accounting for the lead-free trend among suppliers.

Parts suppliers may also be able to switch to the new electrocoat quicker and easier than the automakers. The performance tests for automotive part coatings are much less time consuming than the extensive durability tests required for the auto body. The dip tanks for automotive parts are also smaller and easier to convert to a new paint formulation, and parts suppliers generally have less paint inventory to manage during the conversion. Although there is no definitive explanation for the lead-free trend among automotive parts suppliers and not OEM's, the suppliers, in this case, may be employing a different strategy in managing environmental compliance, by investing in a technology which eliminates the need for extensive environmental management systems. The following is one parts supplier's perspective on lead-free electrocoat: "Heavy metals are damaging to the environment, and their use entails expensive measures such as wastewater treatment and disposal. While these processes can be controlled, complete elimination of heavy metals from as many products as possible is a better option. Enhanced environmental awareness is clearly supported by customers. The conversion to an unleaded electrocoat system was therefore the first step towards an environmentally friendly coating process."[10]

4.2 Impact of Future Regulations on Automotive Electrocoating

As the human health and environmental impacts of lead exposure have become better understood, the government has increased its regulation of lead in products and processes. Leaded gasoline and most lead paints were almost completely banned in the U.S. during the 1960's and 1970's, and more recently, lead in drinking water and lead paint on residential buildings have been the focus of increased regulation. Future restrictions on lead in paints, finished products, and in manufacturing processes may necessitate the use of lead-free electrocoat systems. Therefore, laws in the U.S. and other countries may impact the current electrocoat process through regulations on manufacturing and restrictions on domestic and export product sales.

Two relevant pieces of legislation include a Minnesota statute and a European Union (EU) Directive. The Minnesota statute specifically prohibits the use of lead in paints and coatings, including automotive primers, starting in 1998. The Ford Motor Company has an assembly plant in the Twin Cities which will be impacted by the regulation, and although Ford has not yet implemented lead-free electrocoat, it plans to test lead-free formulations in the Twin Cities plant in the immediate future. The EU directive chooses, instead, to regulate lead in vehicles directly. Article 4, Section d of the proposed, 1996 directive states that "the use of lead and mercury (except in batteries), cadmium, hexavelant chromium and PVC is phased out in vehicles put on the market after 1 January 2002."[31] Although the directive is not final and an exception may be made for auto body electrocoats, the directive could have important consequences on current electrocoating practices. Unlike the Minnesota regulation which affects one automobile assembly plant, the EU directive applies to all vehicles sold in the EU, including all U.S. exports to the region.

In addition to regulations on lead in products and processes, hazardous waste regulation is also an important factor. As discussed in Chapter 3, the future cost of hazardous waste disposal is expected to rise due to increased regulation and difficulty siting new landfills. The trend in environmental regulation appears to be toward increased restrictions on the use and disposal of lead by industry, thereby threatening the future feasibility of lead use in automotive priming. The automakers are aware of these trends, and Chrysler, Ford, and GM are each researching and experimenting with lead-free alternatives. The decision to implement lead-free now or to wait for regulation may depend on how the automaker views the potential for competitive advantage, as discussed in the previous section, and how the alternatives reflect corporate environmental policy.

4.3 Corporate Environmental Policy

The decision to implement a pollution prevention project may be based on total cost analysis results, competitive advantage, impending regulation, and/or congruence with corporate environmental policy. Environmental policy in the automotive industry has developed rapidly since the early 1990's. General Motors, for example, adopted the GM Environmental Principles in 1991 as its first explicit, corporate statement about GM's environmental responsibilities worldwide. In 1994, GM became the first Fortune-50 company to endorse the CERES (Coalition for Environmentally Responsible Economies) Principles.[32] Public environmental statements may give some insight into corporate environmental policy; however, evidence of actions supporting the statements may be more important. Environmental policy in the automotive industry is generally moving toward proactive versus reactive responses to environmental issues. Evidence of this may be found in cooperative environmental initiatives between the automakers, government agencies, and community groups. Pollution prevention programs and projects implemented by automakers may further illustrate more proactive policies. Most or all of the automakers are involved in corporate pollution prevention programs, the Ohio Prevention First program with the Ohio EPA, the EPA's 33/50 Program to reduce priority chemicals, including lead, and the Automotive Pollution Prevention Project to reduce Great Lakes Persistent Toxics, including lead. The lead-free, pollution prevention project may therefore be well-aligned with the environmental policies of the U.S. automotive manufacturers.

Chapter 5. Conclusions and Recommendations

The following conclusions result from the investigation of a total cost analysis of a pollution prevention project in automotive electrocoating. These findings are based on the comparison between a lead-free, auto body electrocoat system and the current, leaded electrocoat system.

1. Total cost analysis provides more complete financial information than a conventional cost analysis by including regulatory costs, liability costs, and less tangible costs.

2. The results of the Tier 0 (usual cost) and Tier 1 (regulatory cost) stages of the analysis show that the lead-free electrocoat project is not financially worthwhile at current market prices. This outcome is sensitive to the lead-free paint price. It is not very sensitive to waste disposal costs or the amount of waste disposed.

3. A lead-free paint price less than a 0.3% increase over lead paint results in the lead-free project being financially worthwhile.

4. At the current lead-free paint price, hazardous waste disposal costs or the amount of waste disposed would have to increase almost 50 times before the lead-free project became financially worthwhile.

5. An automaker's valuation of the Tier 2 and Tier 3 liability and less tangible costs determines the results of the total cost analysis. A high valuation may result in the lead-free electrocoat project being financially worthwhile. Different automakers may therefore arrive at different results from the total cost analysis.

6. Strategic considerations show that 1) lead-free electrocoats may offer a competitive advantage, 2) regulation may necessitate the use of lead-free electrocoats in the near future, and 3) the implementation of lead-free electrocoats supports the corporate environmental policies of automakers.

Based on the above conclusions from the total cost analysis of lead-free electrocoat, the following actions are recommended.

1. Total cost analyses should be conducted to assist in the evaluations of large-scale, pollution prevention projects. Because parts of the analysis may be subjective, it is further recommended that an impartial party conduct the analysis.

2. In addition to financial considerations, the strategic importance of a pollution prevention project should be considered in the decision-making process.

3. Automakers should implement lead-free electrocoat if they 1) place a high value on reduced liability and less tangible benefits, 2) view the technology as a significant competitive advantage, 3) want to precede future regulation, and/or 4) view the project as an important reflection of their corporate environmental policies.

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