

FINAL REPORT

**DEVELOPMENT OF A METHOD TO EVALUATE THE TECHNICAL
AND ENVIRONMENTAL FEASIBILITY OF PARTICULAR POLLUTION
PREVENTION OPPORTUNITIES**

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(The opinions, findings, and conclusions expressed in this
report are those of the author and not necessarily
those of the sponsoring agencies.)

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ABSTRACT

The Virginia Department of Transportation (VDOT) is obligated by House Joint Resolution 453 passed in 1995 by Virginia's General Assembly to develop and implement a pollution prevention (P2) program. The primary purpose of this study was to develop a protocol whereby VDOT could quickly and economically evaluate the feasibility of implementing P2 opportunities identified as requiring additional study. In addition, three P2 opportunities, the use of aqueous parts washers, recycled plastic lumber, and lead acid battery extenders, were evaluated using the developed protocol.

Evaluation criteria taken from various literature sources were used to develop the protocol. After using the protocol to evaluate the three P2 opportunities in question, the researcher concluded that the protocol will be a useful tool for VDOT to use when determining what opportunities to implement as part of its agency-wide Pollution Prevention Plan.

With regard to the P2 opportunities evaluated, the researcher concluded that (1) aqueous parts washers were comparable or superior to solvent-based washers economically, technically, and environmentally; (2) recycled plastic lumber suffers from quality control problems, making it impractical to use for signposts; and (3) although lead acid battery extenders show great promise, little technical information is available to substantiate vendor claims.

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INTRODUCTION

The Virginia Department of Transportation (VDOT) is obligated by House Joint Resolution 453 passed in 1995 by Virginia's General Assembly to develop and implement a pollution prevention program. *Pollution prevention* (P2) can be defined as those practices that reduce or eliminate the use of energy, materials, water, or any other resource and that protect natural resources through conservation (Ministry of Environment and Energy, 1993). P2 is considered the most cost-effective form of environmental protection because it emphasizes reducing waste at the source of generation rather than managing wastes after they are generated.

P2 implementation is often difficult for most agencies and businesses. The initial, and often most difficult, hurdle is identifying P2 opportunities (Boyd, 1998). In addition, many agencies do not support P2 projects because environmental funding has historically been focused on regulatory compliance activities (U.S. Environmental Protection Agency [EPA], 1995) and end-of-the-pipe solutions. A low return on investment is not uncommon with many good P2 ideas because many of the higher payback ideas that could be implemented easily are already in practice (Pelley, 1997). Nagging technical issues and regulatory barriers often make it safer and easier for agencies to proceed with business as usual. Making implementation even more difficult is the fact that P2 planning is a comprehensive and continual process of evaluating and changing business practices; it is not a one-time assessment (Ministry of Environment and Energy, 1993). Many agencies and businesses are simply not willing to dedicate a significant portion of a group's or an individual's time to this implementation process.

VDOT's Environmental Division is developing a P2 plan for the agency. As part of this plan, division personnel and representatives from the Administrative Services, Structure & Bridge, Materials, and Traffic Engineering divisions developed a list of nearly 100 potential P2 opportunities (see the Appendix). The ideas identified ranged from the very simple to the extremely complex. VDOT's Environmental Program Manager and the researcher prioritized the list based on anticipated ease of implementation, technical feasibility, and anticipated benefits. Each idea was placed in one of three categories: implement immediately, discard or postpone indefinitely, or study more thoroughly.

Those that were recommended for immediate implementation were simple ideas that required little or no costs to implement and were clearly beneficial from a P2 perspective (e.g., power down computers on weekends). Ideas that were discarded either were deemed too difficult to implement or were determined to be far too complex or expensive when compared

with the environmental benefits that would be gained (e.g., change toll structure to increase ridesharing). A total of 32 items did not fit in either of these categories and were rated as requiring additional study.

PURPOSE AND SCOPE

The primary purpose of this study was to aid VDOT with implementing its P2 plan. To achieve this, the study had two objectives: (1) develop a method whereby VDOT could quickly and economically evaluate the feasibility of implementing P2 opportunities identified as requiring additional study, and (2) evaluate some of the P2 opportunities previously identified as requiring additional study to determine their potential for implementation. The opportunities evaluated were the use of aqueous parts washers, the use of recycled plastic lumber, and the use of lead acid battery extenders.

METHODOLOGY

Three tasks were performed to carry out the objectives of this study: a literature review was conducted, a protocol was developed to evaluate P2 opportunities, and three P2 opportunities were evaluated using the protocol developed.

Literature Review

A literature review was conducted to determine how other state and federal agencies and private businesses prioritize and evaluate P2 opportunities, i.e., the specific criteria used to determine whether an idea is worth implementing. VIRGO, DIALOG, and TRIS were used to conduct this search. An Internet search was also conducted since the researcher found that many state and federal agencies publish P2 information on their web sites. Several private, non-profit web sites dedicated to P2 were also examined.

Development of Protocol to Evaluate P2 Opportunities

Evaluation criteria, weighting values, methods, and other findings from the literature were examined for applicability within VDOT. This information was then tailored to establish a step-by-step method to evaluate potential P2 opportunities in VDOT.

Evaluation of P2 Opportunities Using Developed Protocol

Three P2 opportunities were selected for evaluation based on the time constraints of the study. A literature review and an Internet search were conducted for each. These searches were

done to obtain information from vendors, to obtain recommendations from businesses and agencies who had implemented these or similar options, and to obtain technical background information concerning the opportunities. In addition, information was gathered from approximately eight VDOT sources on the respective processes or products that each opportunity was to replace. The sources were selected based on their potential knowledge of the subject area and from recommendations by VDOT's Environmental Program Manager. The individuals consulted ranged from VDOT traffic engineers to VDOT field personnel from area headquarters. The information was gathered by way of e-mails, telephone interviews, personal interviews, and site visits. The data were subsequently used in the analysis of each opportunity by following the P2 evaluation process previously developed. Implementation recommendations were made based on the results of the analyses.

RESULTS AND DISCUSSION

Literature Review

A moderate amount of information was available in the literature regarding ways to evaluate P2 options. Almost all of the approaches were different, yet most had criteria in common. Each had different areas of emphasis, and all had different ways of arriving at a final determination on implementation. Nearly all the criteria fell into one of three categories: economic evaluation, technical feasibility, and environmental feasibility.

Economic Evaluation

Regardless of the intended audience (for-profit private businesses or government agencies), a great deal of emphasis was placed on the costs associated with P2 implementation. Information relating to private businesses was centered on ensuring that a profit would be made as a result of implementing a particular option. Information for federal agencies, on the other hand, was designed to ensure that the option chosen would be one of the least expensive alternatives available and, more important, less expensive than the existing setup. In nearly all cases reviewed, however, the authors repeatedly stated that obtaining an accurate estimate of both the total costs and total savings associated with a P2 option was difficult (Boyd, 1998; U.S. Department of Energy, 1993a; Kennedy, 1994; U.S. EPA, 1995). As a consequence, there are numerous methods of assessing P2 project costs.

The U.S. EPA's *Federal Facility Pollution Prevention Project Analysis* (1995) indicated that traditional methods of analyzing most environmental alternatives do not consider all costs and savings. Most methods incorporate too few cost areas over too short a period of time. This results in inadequate justification for P2 opportunities. It is not uncommon for the economic evaluation to consist of a simple comparison of the purchase prices of two or more alternatives. The report stated that this is typically a poor indicator of the total cost of an alternative. The report went on to describe more accurate methods of financial analyses that are advocated by

federal agencies. Three methods of comparing financial performance were described: total cost accounting, total cost assessment, and life cycle cost assessment.

Overall, the U.S. EPA recommended increasing the value of the economic analysis by expanding the costs/savings inventories for a project. Other than just the purchase price, items to include are additional materials, preparation costs, planning and engineering costs, training costs, permitting costs, utility costs, and insurance costs. Another recommendation was to expand the time horizons over which P2 projects are evaluated to a minimum of 5 years. In many cases, it takes years for the savings of a P2 item to materialize. The final recommendation for a more reasonable economic analysis of P2 opportunities was to compare financial performance by way of one of three indicators: payback period, net present value, and internal rate of return. Two of these, payback period and net present value, are usually used by government agencies comparing P2 alternatives.

Payback period analysis is most commonly used by federal agencies. It is a way of estimating the time it will take to recover the costs of a particular project. This allows for a direct comparison of the payback periods for different projects. Alternatively, a threshold payback period can be established, and any P2 alternative accepted must fall within the threshold. The formula given to calculate payback period is:

$$\text{Payback period (years)} = \text{Startup costs} / (\text{Annual benefits} - \text{Annual costs}).$$

The net present value method of economic analysis is based on the concept that a given amount of money today will be worth less at some time in the future. This method discounts both costs and revenues related to a project in future years. The discount rates used in determining the cost of projects are obtained from the U.S. Office of Management and Budget. At the time the source document was printed, the published discount rates ranged from 7.3 percent for 3-year investments to 7.9 percent for 10-year investments. Net present value is calculated using the following equation:

$$\text{Net present value} = \text{Initial investment (a negative number)} + (\text{Discounted cash inflows} - \text{Discounted cash outflows}).$$

The higher the net present value, the more attractive a project is in economic terms. Because of the nature of P2 projects, the net present value of a project will often be negative. Using the net present value is said to be a good method for comparing alternatives that will not produce a profit (e.g., disposal costs). The method is used by both federal agencies and private sector businesses.

Several other methods of determining the long-term financial implications of P2 items were found. They ranged from the commonly known profitability index to very specific methods such as the General Electric method (U.S. EPA, 1992). A number of software packages designed specifically for determining the financial implications of P2 option implementation also exist. No matter what method is used to compare the financial performance of P2 opportunities, the U.S. EPA (1995) emphasized repeatedly that the most important thing is to expand the existing economic analysis method as much as possible to something beyond a simple

comparison of the purchase prices of alternatives. Many think that the simpler methods, although not so accurate as some of the more complex methods available, are best because they are the most likely to be used (U.S. EPA, 1992). Despite the ability to develop specific numbers associated with particular aspects of P2 implementation (e.g., purchase price, operating costs, maintenance costs), not all costs and benefits are so easily determined. Placing dollar amounts on items such as the potential for accidents, liability costs, remediation costs, and legal fees is difficult. Determining how large these costs could be and if or when they will occur can be nearly impossible. This is due in part to the complexity associated with assigning risk to hazardous substances and to the ever-changing regulations governing most environmental areas. Regardless of these problems, the types of benefits related to different alternatives need to be considered on a consistent basis as part of the economic analysis (U.S. Department of Energy, 1993b; U.S. EPA, 1992).

Technical and Environmental Feasibility

Methods for determining technical feasibility and environmental feasibility were lumped together in some literature sources as criteria were provided to determine if an option was environmentally—and, therefore, technically—feasible. Other sources treated environmental feasibility and technical feasibility as separate questions, indicating that just because something is environmentally feasible does not mean that it is technically feasible, and vice versa. For the purposes of describing what was found in the literature, these two are combined in the discussion here.

The key to determining the technical feasibility of a P2 option is simply a matter of finding out if the option is likely to work in a specific application. With few exceptions, there are two ways of preventing pollution: product changes and process changes. Depending on the complexity of the option, the technical feasibility analysis may be relatively quick or several people and an extensive amount of effort may be required (Ministry of Environment and Energy, 1993).

The Canadian Ministry of Environment and Energy's *Pollution Prevention Guidance Document* (1993) provided specific technical and environmental evaluation criteria, which included the following, questions:

- Will it reduce waste?
- Is the system safe for workers?
- Will product quality be improved or maintained?
- Is there space available in the current facility?
- Are the new equipment, materials, or procedures compatible with our production operation procedures?

- Will additional personnel be needed (with special expertise)?
- Are the utilities necessary to run new equipment available?
- How long will the current process be interrupted during the transition?
- Will other environmental problems be created?

The report states that determining environmental feasibility is not always so straightforward as determining technical feasibility. Once products or processes are changed, there is a risk that the pollution will be shifted from one medium to another. With respect to the environmental feasibility, the primary questions to ask are:

- What is the effect on the number and toxicity of waste streams?
- Is there a risk of transfer to other media?
- What is the change in energy consumption?
- What is the environmental impact of alternate input materials?

Another report by the U.S. Department of Energy, *Prioritization of Pollution Prevention Options Using a Value Engineering Approach* (1993b), provided a variety of criteria by which to evaluate the feasibility of P2 options. Several (in addition to the economic feasibility criteria already described) that are related to environmental and technical feasibility included the effect on health and safety, effect on operations, technical risk, time required for implementation, regulatory compliance required, effect on public image, and long-term liability. Depending on the option being evaluated, some of the criteria may be redundant or some may not be applicable. The report suggests that evaluators should add or drop criteria as necessary.

The report provides a ranking chart for each criterion used. P2 options are placed in one of five categories for each criterion and given scores from 0 to 10. The scores are then multiplied by a weighting factor according to the relative importance of the criteria. These weighting factors can be adjusted according to the importance a particular criterion has to the organization. Recommended weighting scores are given for all criteria. The rankings are then multiplied by the weighting factor and the products for each are then summed, providing a final score for each option. The options with the highest scores then become the highest priority P2 options to implement.

The U.S. EPA's *Federal Facility Pollution Prevention Planning Guide* (1994) recommends similar evaluation criteria: environmental compliance, mission impact, environmental benefits, ease of implementation, community concerns, environmental justice considerations, worker safety, impact of future compliance, and resource consumption. Specific examples of agencies applying similar criteria with customized rankings are given.

The U.S. Department of Energy's 1993 report entitled *Model Pollution Prevention Opportunity Assessment* (1993a) gives recommendations on how to identify P2 options based on analyzing and improving existing processes. Different levels of assessment are recommended depending on the complexity of the process being changed and the P2 option(s) under consideration. By employing different levels of assessment, time and money are less likely to be wasted on studying P2 options that will ultimately be screened out. Specific criteria recommended for option evaluation include expected change in the type or amount of waste generated, ultimate effect on products being developed, effects on employee health and safety, time needed for implementation, and ease of implementation.

Pojasek (1997) stated that the use of checklists or matrices is insufficient for understanding and finding P2 alternatives for existing processes. He maintained that what he terms *process mapping* is necessary in order to understand and see the relationships among different types of work steps within a given process. He advocated putting together a process mapping team consisting of people from various departments within the organization. The process maps themselves are made up of boxes and arrows. The boxes represent work steps, and the arrows represent the movement of materials between steps. According to Pojasek, both an "as-is" map and a "to be" map should be developed so that direct comparisons can be made between the two. He recommended that the maps consist of several layers, each different in its level of detail. The first layer should be a broad overview, with very few details; it normally should contain no fewer than three and no more than six steps. Each step in the first layer should have its own more detailed second layer map. The development of this layer requires significantly more investigation into how a process works. The addition of more layers continues until the entire process is completely represented. Pojasek advocated developing the process maps on a computer where they can be easily updated and linked to spreadsheets for keeping track of such things as an inventory listing. Ultimately, the process map developed will reveal areas where losses are occurring and unnecessary inputs are being made, allowing for elimination, simplification, and improvement of the work steps in a given process.

Development of P2 Protocol

VDOT is a large and complex organization; its size and diversity only add to the already difficult task of implementing P2 opportunities. Conversely, there is a great potential for VDOT to reduce the amount of waste it produces and the natural resources it consumes if the proper opportunities are implemented. The seven-step protocol developed to evaluate existing and newly developed P2 opportunities is shown in Figure 1. The specific criteria recommended were taken from the literature summarized earlier. Although the protocol developed closely follows the one outlined by the U.S. Department of Energy (1993b), no one particular protocol was followed precisely. Instead, specific items that were applicable to VDOT based on its mission and purpose, the number of divisions affected, and the quantities and types of pollution were selected and combined.

Overall, the method is intentionally simple so that it is more likely to be applicable to more divisions within VDOT. As with most of the methods reviewed and presented earlier, this recommended protocol will not apply to all situations and, therefore, in particular instances can

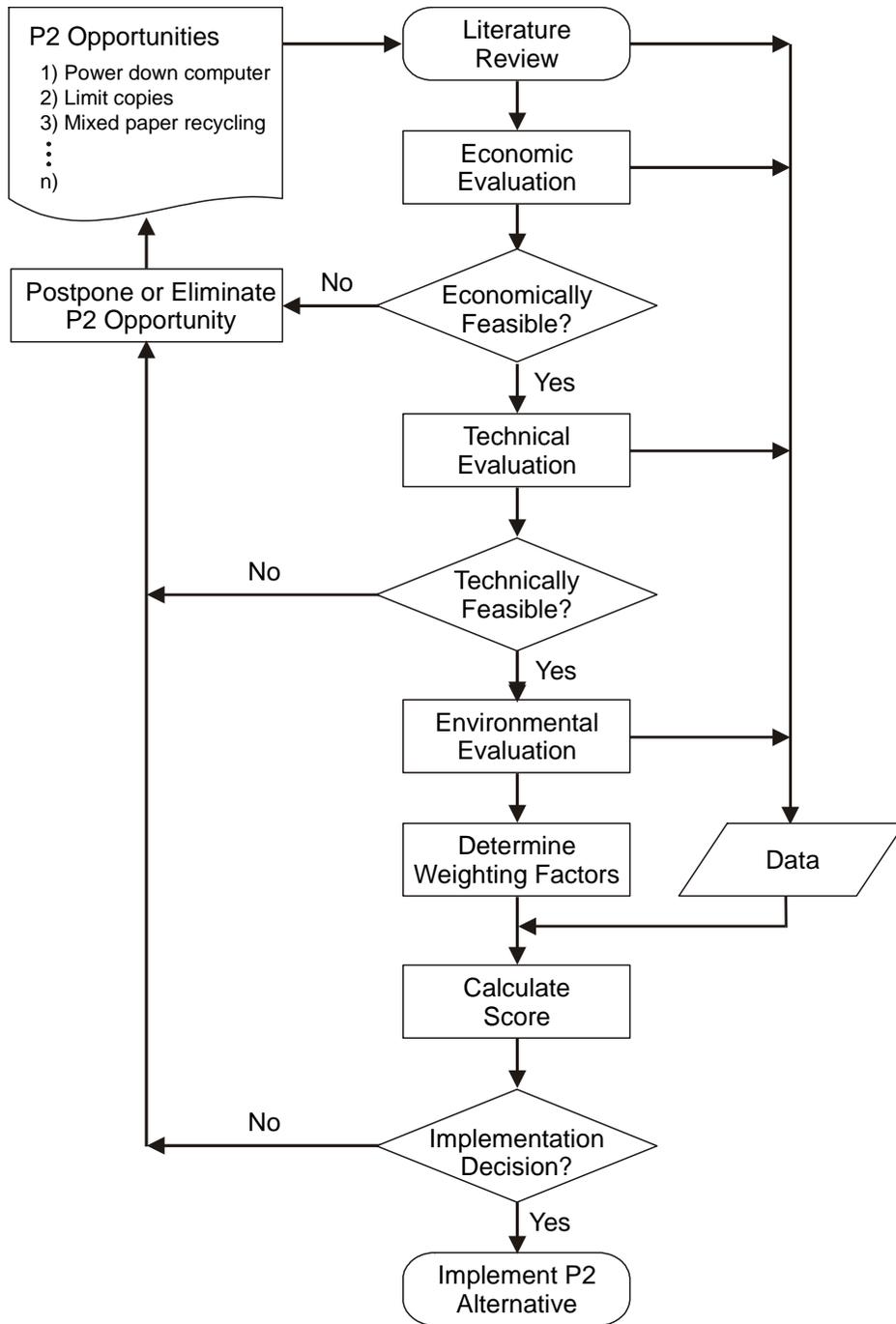


Figure 1. P2 Opportunity Evaluation Protocol

and should be altered to meet the needs of the user. Also, because VDOT has never developed an organized P2 program, there should be a large number of alternatives that should be relatively easy to implement. As these “easier” options are implemented over time, it may be necessary to rework the P2 evaluation so that all options being considered for implementation undergo a greater degree of scrutiny.

Step 1—Collect the Data

Each evaluation of a P2 opportunity should begin with a literature review to determine if and how others have implemented a similar alternative. Depending on the option, significant or very little information may be found. Ideally, transportation-related applications should be investigated first, as these will be the most similar to VDOT's P2 opportunities and objectives. In addition to specific case studies, relevant technical information should be collected by way of surveys and site visits. Specific information sought will depend on the P2 alternative but should be geared toward answering the questions in the economic, technical, and environmental components of the evaluations. The general findings of the data collection effort, including a description of the existing product or process and the proposed alternative, should be documented so they can be referenced later if necessary.

Step 2—Conduct the Economic Evaluation

An economic evaluation should be conducted for each alternative being considered. At the very least, the payback period should be calculated as previously described. This does not require extensive data to calculate and will provide a specific number to allow for comparisons of alternatives. Net present values should also be calculated for alternatives that require a significant amount of capital to implement. This will provide a second number to use for comparison when multiple opportunities are considered.

Undoubtedly, there will many alternatives that could be environmentally beneficial but would cost too much to implement. If it is discovered that an alternative is not economically feasible, then the alternative should be dropped from consideration or its implementation should at least be postponed until conditions make it more economically viable. If it is determined that an alternative is economically feasible (i.e., the savings are equal to or greater than the costs), the alternative should be given a score of 1 if the savings and costs are approximately equal or if the payback period is 2 to 3 years. A score of 2 should given if the savings are significantly greater than the costs or if the payback period is less than 2 years.

Depending on the complexity of the alternative being considered, the economic evaluation may be relatively simple or complex and time-consuming. As was stated in the literature, if this process becomes too complicated and time-consuming, the likelihood of it being followed will diminish. With few exceptions, those individuals performing the evaluation will have little or no experience in conducting economic evaluations. If an evaluation from the literature can be referenced, it may complement the evaluation performed by VDOT personnel, but this will depend on the degree of similarity between the referenced study and the situation being evaluated. Therefore, this step, although one of the most important to VDOT, should be kept as simple as possible.

Step 3—Conduct a Technical Feasibility Evaluation

The technical and environmental feasibility analyses should be conducted separately. In essence, the technical evaluation is designed to determine if the alternative will affect product or service quality or the safety of VDOT employees or the general public. For VDOT, it is recommended that the technical evaluation be conducted first and the P2 opportunity eliminated or postponed if it is not found to be feasible from a technical perspective. The criteria selected to evaluate the technical feasibility of an opportunity and the scoring criteria are as follows:

1. *Is the alternative safe for employees and the general public?*
 - 2 – decreases health and safety risk
 - 1 – does not affect health and safety risk
 - 0 – increases health and safety risk

2. *Will product or service quality be maintained?*
 - 2 – increases product or service quality
 - 1 – does not affect product or service quality
 - 0 – decreases product or service quality

3. *Is the new product or process compatible with other operations that are not changing?*
 - 2 – completely compatible with other operations
 - 1 – compatible with only minor modifications
 - 0 – compatible only after major modifications

4. *How long will it take to implement the option?*
 - 2 – implementation will take less than 6 months
 - 1 – implementation will take 6 to 18 months
 - 0 – implementation will take more than 18 months.

An option that does not receive a score of 4 or higher or one that receives two or more 0s should be eliminated from consideration. Those options that are not eliminated should next be evaluated for environmental feasibility.

Step 4—Conduct an Environmental Feasibility Evaluation

Determining environmental feasibility is likely the most difficult task in the P2 evaluation process. In order to assess if an option is environmentally beneficial, one must understand both the existing process or product that is to be altered or replaced and the new process or product. In addition, unlike the economic and technical evaluations, a true environmental evaluation will consider not only what happens within the boundaries of the organization, but also what happens outside these boundaries (i.e., will the process or product generate more waste or consume more resources elsewhere?). An extensive amount of time can be consumed in answering all the questions related to environmental feasibility. This is why this step is near the end of the

process. Only those P2 opportunities that are deemed economically and technically feasible should undergo the environmental evaluation.

The criteria for evaluating the environmental feasibility and their scoring criteria are as follows:

1. *Is the overall quantity of waste reduced:*
 - *for VDOT?*
 - 3 – quantity of waste is significantly reduced
 - 2 – quantity of waste is reduced
 - 1 – no effect on quantity of waste
 - 0 – increases quantity of waste
 - *outside VDOT?*
 - 3 – quantity of waste is significantly reduced
 - 2 – quantity of waste is reduced
 - 1 – no effect on quantity of waste
 - 0 – increases quantity of waste
2. *Is the toxicity of waste produced reduced?*
 - 3 – toxicity of waste is significantly reduced
 - 2 – toxicity of waste is reduced
 - 1 – no effect on toxicity of waste
 - 0 – increases toxicity of waste
3. *Is there a transfer of waste to other media?*
 - 3 – no transfer of waste to other media
 - 2 – transfer of waste is minimal
 - 1 – transfer of waste is smaller than overall reduction
 - 0 – transfer of waste is greater than overall reduction
4. *Is there a reduction in energy/natural resource consumption?*
 - 3 – significant reduction in consumption
 - 2 – reduction in consumption
 - 1 – no change in consumption
 - 0 – increase in consumption
5. *Is the alternative acceptable to regulators?*
 - 3 – directly enhances regulatory compliance
 - 2 – indirectly enhances regulatory compliance
 - 1 – no effect on regulatory compliance
 - 0 – has a negative effect on regulatory compliance
6. *What is the public perception of the alternative?*
 - 3 – significantly improves public image
 - 2 – improves public image

- 1 – little or no effect on public image
 - 0 – lowers public image
7. *Will long-term liability be reduced?*
- 3 – significantly reduces long-term liability
 - 2 – reduces long-term liability
 - 1 – little or no effect on long-term liability
 - 0 – may increase long-term liability.

Step 5—Weight the Evaluation Criteria

After a score for each of the evaluation criteria has been determined, a weighting factor should be given for each. Multiplying criteria scores by an independent weighting factor allows for customization of the evaluation process depending on the importance of the different areas to the evaluator. The emphasis a particular area is given will likely be different for different VDOT divisions. The weighting factors may also change over time, depending on changes in regulations, departmental emphasis areas, and the political climate. The weights particular criteria are given may also be based on the availability and quality of data obtained. The weighting values may range from a low of 5 to a high of 10. Suggested scoring weights, which were taken primarily from the U.S. EPA’s report entitled *Prioritization of Pollution Prevention Options Using a Value Engineering Approach* (1993b), are shown in Table 1.

Table 1. Suggested Weighting Values for Evaluation Criteria Scores

Area	Weighting Value
Economic analysis	8
Safety	8
Product/service quality	7
Compatibility	6
Implementation time	5
Waste quantity in VDOT	6
Waste quantity out of VDOT	6
Toxicity	5
Media transfer	5
Energy consumption	5
Regulatory acceptance	10
Public perception	6
Long-term liability	5
Total	82

Step 6—Calculate the Score of the P2 Option

In this step, the score for each criterion is multiplied by the respective weighting factor. The sum of the products is then divided by the total of the weighting factors to provide the final score for the P2 option. Options receiving a score below 1.3 should not be implemented. Those receiving a score of 1.3 or higher should be implemented. The threshold of 1.3 is based on an option receiving scores of at least 1 (i.e., no negative effects) on the economic and technical

criteria and scoring an average of 1.5 on each of the environmental criteria. Final scores for multiple options can be compared to select the most advantageous opportunity.

Step 7—Develop a Report

A final report should be developed for each alternative that undergoes the entire P2 evaluation process so as to document the findings of the evaluation and the reasoning behind the final implementation decision. At a minimum, the report should include the following sections: description of alternative, data collection, economic evaluation, technical evaluation, environmental evaluation, scoring calculation, and implementation recommendation. This information will be useful if the evaluation needs updating if required by changes in the regulations or technology.

Assessment of P2 Opportunities

Aqueous Parts Washers

Description of Alternative

Various solvents are commonly used to clean parts as a necessary part of vehicle maintenance and repair. The solvents used to remove oils and greases and are very effective because of both their chemical and physical properties. Because most of the solvents typically used in parts washers are petroleum based, there are numerous environmental issues related to their use and disposal. Typical wastes generated from solvent-based parts washers include spent filters, waste sludge, and waste solvents (Lowell, 1995). Aqueous parts washers are now being considered as a P2 alternative to petroleum-based parts washers, attributable in part to U.S. EPA restrictions on chlorofluorocarbons (Hanson et al., 1997; Presley & Finney, 1995). Aqueous cleaners do not deplete ozone and contain few if any volatile organic compounds (Pacific Northwest Pollution Prevention Resource Center, 1996).

Aqueous parts washers use a high-volume spray to remove contaminants mechanically from the parts being cleaned. This process, termed *impingement*, is one of the major cleaning properties of aqueous parts washers. Impingement is obtained through various methods including open-air sprays, submerged pressure sprays, part agitation, and ultrasonics (Pacific Northwest Pollution Prevention Resource Center, 1996; Rowney et al., 1992). Usually, an alkaline cleaning solution is added to the water to aid in the removal of oil and grease. The cleaning solutions are normally biodegradable and are not considered hazardous, but they can etch aluminum, tarnish copper alloys, remove zinc, and damage coatings (Hanson et al., 1997). In addition to the mechanical forces of the water and the chemical processes of the cleaning solutions, the cleaning properties are increased further by heating the water in the system to 70° C to 90° C.

Data Collection

In addition to the literature review, e-mail surveys were sent to personnel in all nine VDOT districts. Personnel from six of the nine districts responded. Of these, interviews were conducted with four VDOT personnel, three VDOT mechanical engineers and one VDOT equipment repair manager, who had begun to use aqueous parts washers in place of solvent-based parts washers. They were asked about how the two systems compared with respect to operation cost, purchase price, waste disposal, and overall effectiveness. In addition, 12 vendors taken from the list of automatic parts washer manufacturers provided by Hanson et al. (1997) were contacted regarding purchase price and normal operations cost.

Economic Evaluation

Aqueous parts washers come in a range of sizes. The survey of vendors found that the average cost of the washers was approximately \$4,600, with an average annual operations cost of approximately \$850. Annual savings could be expected based on a reduction in the costs related to disposal of the waste streams. However, this would be highly dependent on the parts being cleaned and the amount of use the washer gets (see the following “Environmental Evaluation”). Based on the findings in the literature reviewed, one may easily assume that disposal costs would be significantly less with the aqueous-based systems but that the operations costs might be higher (Hanson et al., 1997; Kennedy, 1994; U.S. Army Center for Health Promotion and Preventive Medicine, 1997a & b).

The four VDOT personnel interviewed found aqueous-based parts washers to be generally more expensive than comparable solvent-based washers. The solvent-based washers were typically rented, and the waste solvent was picked up on a set interval as a part of this contract. The aqueous parts washers were said to cost less to operate, but specific costs depended on the amount of cleaning solution used and the frequency of waste disposal (J. Ryles, VDOT’s Richmond District Repair Manager, personal communication, October 12, 1999; D. Wright, VDOT’s Lynchburg District Mechanical Engineer, personal communication, March 23, 2000).

According to a study done by the U.S. Army Center for Health Promotion and Preventive Medicine (1997b), the costs associated with the purchase of these aqueous-based machines varied from \$3,000 to more than \$20,000 for those large enough to contain entire engines. The average annual operating cost was approximately \$1,900. The same study found that the annual cost savings resulting from a decrease in waste stream disposal costs was \$6,760, resulting in a payback period of approximately 1.3 years.

It was generally found that aqueous parts washers became more economically viable as the cost assessment methodology became more comprehensive (Hanson et al., 1997). In one study (Kennedy, 1994), eight sites were evaluated. Operational costs were reduced by 75 percent in three and by 95 percent in the other five.

This economic evaluation of aqueous parts washers yielded a score of 2.

Technical Evaluation

Depending on the specifics of the system, the water in the system is recycled and used for multiple cleanings. At some point, however, the cleaning efficiency of the system is reduced because the wash water itself becomes too contaminated. Some washers are equipped with filters or skimmers to reduce the contaminant concentration of the wastewater, thereby allowing the system to be used longer prior to clean out. Numerous types of filters are available, ranging from cellulose and ceramic membranes to closed systems containing contaminant-eating microbes that help keep the filter from fouling (Aviva, 1998; Presley & Finney, 1995). Other systems use evaporators to drive off the water in the system prior to cleaning, leaving only solid contaminants. Maintenance or cleanout requirements associated with aqueous cleaners varied drastically. The average interval between system cleanouts ranged from 3 to 6 months (Adams & Larson, 1995; Hanson et al., 1997).

The technical evaluation for aqueous parts washers yielded a score of 5.

Technical Evaluation Score Sheet for Aqueous Parts Washers	
1. Is the alternative safe for employees and the general public? 2 – decreases health and safety risk 1 – does not affect health and safety risk 0 – increases health and safety risk	Score: 2
2. Will product or service quality be maintained? 2 – increases product or service quality 1 – does not affect product or service quality 0 – decreases product or service quality	Score: 1
3. Is the new product or process compatible with other operations that are not changing? 2 – completely compatible with other operations 1 – compatible with only minor modifications 0 – compatible only after major modifications	Score: 1
4. How long will it take to implement the option? 2 – implementation will take less than 6 months 1 – implementation will take 6 to 18 months 0 – implementation will take more than 18 months	Score: 1
TOTAL SCORE: 5	

Environmental Evaluation

Probably the most significant concern related to the use of aqueous parts washers is the proper disposal of the wastewater and sludge resulting from the system cleanout. Numerous studies have analyzed the chemical makeup of the residual wastes. In summary, the concentrations and chemicals found in the waste streams are dependent on several variables, including the type of cleaning solution used, the types of parts cleaned, the types of contaminants found on the parts, the filtering mechanism used for the system, and the maintenance interval. In a study done by the Army Corps of Engineers (Hanson et al., 1997), of the 70 percent of installations that tested the waste from the aqueous parts washers, all had waste having

Environmental Evaluation Score Sheet for Aqueous Parts Washers

1. Is the overall quantity of waste reduced:

- for VDOT?
 - 3 – quantity of waste is significantly reduced
 - 2 – quantity of waste is reduced
 - 1 – no effect on quantity of waste
 - 0 – increases quantity of waste

Score: 2

- outside VDOT?
 - 3 – quantity of waste is significantly reduced
 - 2 – quantity of waste is reduced
 - 1 – no effect on quantity of waste
 - 0 – increases quantity of waste

Score: 2

2. Is the toxicity of waste produced reduced?

- 3 – toxicity of waste is significantly reduced
- 2 – toxicity of waste is reduced
- 1 – no effect on toxicity of waste
- 0 – increases toxicity of waste

Score: 2

3. Is there a transfer of waste to other media?

- 3 – no transfer of waste to other media
- 2 – transfer of waste is minimal
- 1 – transfer of waste is smaller than overall reduction
- 0 – transfer of waste is greater than overall reduction

Score: 1

4. Is there a reduction in energy/natural resource consumption?

- 3 – significant reduction in consumption
- 2 – reduction in consumption
- 1 – no change in consumption
- 0 – increase in consumption

Score: 1

5. Is the alternative acceptable to regulators?

- 3 – directly enhances regulatory compliance
- 2 – indirectly enhances regulatory compliance
- 1 – no effect on regulatory compliance
- 0 – has a negative effect on regulatory compliance

Score: 2

6. What is the public perception of the alternative?

- 3 – significantly improves public image
- 2 – improves public image
- 1 – little or no effect on public image
- 0 – lowers public image

Score: 1

7. Will long-term liability be reduced?

- 3 – significantly reduces long-term liability
- 2 – reduces long-term liability
- 1 – little or no effect on long-term liability
- 0 – may increase long-term liability

Score: 2

TOTAL SCORE: 13

contaminants exceeding regulatory limits, thereby requiring disposal as a hazardous waste. The particular contaminants ranged from heavy metals to petroleum hydrocarbons. Some VDOT installations are able to dispose of the filtered waste with used oil waste. Toxicity characteristic leaching procedure tests should be done on all waste from these systems to determine the proper method of treatment or disposal (Adams & Larson, 1995).

The environmental evaluation for aqueous parts washers yielded a score of 13.

Scoring Calculation

It is recommended that the weighting for this P2 alternative follow that recommended by the protocol. With the possible exception of the economic data, the scores are based on a combination of VDOT field data and a number of directly applicable research findings in the literature.

The final score for aqueous parts washers was 1.6.

Final Score Sheet for Aqueous Parts Washers			
Area	Area Score	Weighting Value	Total Score
Economic Evaluation	2	8	16
Technical Evaluation			
safety	2	8	16
product/service quality	1	7	7
compatibility	1	6	6
implementation time	1	5	5
Environmental Evaluation			
waste quantity in VDOT	2	6	12
waste quantity out of VDOT	2	6	12
toxicity	2	5	10
media transfer	1	5	5
energy consumption	1	5	5
regulatory acceptance	2	10	20
public perception	1	6	6
long-term liability	2	5	10
Total	20	82	130
Final Score (total score/weighting value): = (130/82) = 1.6			

Implementation Recommendation

Because the final score was more than 1.3, the use of aqueous parts washers is recommended over the use of traditionally used solvent-based parts washers. The aqueous systems have well-documented environmental advantages, are technically feasible, and are economically competitive when compared to solvent-based machines.

Recycled Plastic Lumber

Description of Alternative

For many years, treated wooden posts have been used to support most medium-to-small signs on the majority of Virginia's primary and secondary roadways. Wood has been the material of choice for several reasons, a primary one being its breakaway properties. There are, however, several drawbacks to the use of wood for signposts. Treated wooden posts have a life cycle of approximately 20 years, but because of warping, twisting, and bowing following installation, it is not uncommon to have to replace them sooner. In addition, it is estimated that approximately 10 percent of the posts purchased by VDOT are deemed useless prior to installation because of warping (J. S. Hores, VDOT's Culpeper District Traffic Engineer, personal communication, January 4, 2000).

If additional signs are to be added to the sign assembly, the entire post must be removed and replaced by a larger post to accommodate the increased height requirement. However, the biggest problem related to the use of treated wooden posts is probably that of disposal. Because of the chemicals used in the treatment process, the posts cannot be recycled but instead must be disposed of in a landfill. This requires storing, hauling, and eventually paying the tipping fee associated with the ultimate disposal.

Recycled plastic lumber is being considered as a possible replacement for treated lumber for some sign assemblies, among other things, such as traffic barricades, guide rail post blockouts, guardrail posts, traffic cones, snow poles, post reflectors, and sound walls (Hag-Elsafi et al., 1999; Schroeder, 1994; Smith, 1996). Federal, state, and local laws, including the Intermodal Surface Transportation Efficiency Act, have encouraged the use of recycled materials in highway construction (Saadeghvaziri & Macbain, 1999). Recycled plastic lumber has become more readily available because of increased domestic-waste recycling resulting from improved recycling technologies, legislative mandates, and increased public awareness (Hag-Elsafi et al., 1999).

Data Collection

Numerous literature sources were available on various aspects of the use of recycled plastic lumber for signposts. Several state departments of transportation including Florida, New Jersey, Oregon, and South Carolina have investigated the use of posts made of this material. Information from these studies ranged from engineering specifications to cost/benefit analyses. Specifications from numerous vendors were obtained from their Internet sites. In addition, at least one residency in each of VDOT's nine districts was surveyed to determine the type and number of posts they install annually and the costs associated with the purchases.

Economic Evaluation

In 1993, Hunt found that, in general, recycled plastic lumber was more expensive than comparable treated lumber. The costs of recycled plastic signposts ranged from 12 to 285 percent more than those of comparable wood products. Hunt concluded that a post 4 in by 4 in by 12 ft (10 cm by 10 cm by 3.66 m) with an average life of 20 years costs approximately \$0.44/year. A comparable recycled plastic post would have to last 25 to 44 years (depending on the variation in costs found between manufacturers) to cost the same. Information from the nine VDOT residencies indicated that they, on average, install more than 1,600 posts each year. The average wooden post used in these installations costs approximately \$19 (\$2.38 per linear foot [\$7.79/m]) and has an average life of just over 17 years. On average, costs per linear foot for 4 in by 4 in (10 cm by 10 cm) recycled plastic lumber were between \$2.00 and \$6.22 per linear foot (\$20.40/m) for material 6 in by 6 in (15 cm by 15 cm). More recent cost estimates for recycled plastic lumber were \$4.18 and \$11.45 per linear foot (\$13.71 and \$37.56/m), respectively (Phoenix, 2000). In general, these prices are approximately 1.75 times greater than those of comparable treated lumber, indicating that the recycled plastic lumber would have to last in excess of 30 years to offset the increased costs.

In summary, it is ill advised to try to read too much into the cost estimations related to recycled plastic lumber. There are tremendous variations in the prices of the products available. In general, though, recycled plastic lumber is significantly more expensive than comparable treated lumber. The additional cost should be offset by the increased durability of these products if expected life estimates are accurate. Unfortunately, most products have not been on the market long enough to provide any significant proof of their ultimate life spans. It does, however, appear that, at a minimum, the life cycle costs of the two types of posts are at least comparable and, therefore, close enough to consider the other aspects of using recycled plastic lumber.

The economic evaluation for recycled plastic lumber yielded a score of *1*.

Technical Evaluation

The Florida Department of Transportation, in conjunction with the University of Florida, has done extensive testing on the use of recycled plastic products in highway construction, including signposts. They conducted numerous tests on fence posts including flexural stress, water absorption, and accelerated oven tests (Ramer & Smith, 1993; Smith, 1996). They found that recycled plastic posts have two distinct areas, the skin and the core, because of the differences in cooling rates during production. The physical properties of these two areas differ significantly. The skin, or outer portion, of the post was found to be up to 4 times stronger than the core in compressive strength. The core has poor strength because of steam entrapment during the manufacturing process. Overall, the compression strengths for the plastic products were not as high as for wood. Tension strengths were slightly higher, whereas flexural strengths were much lower. The posts were resistant to microorganisms, insects, and water absorption (Amirkhanian, 1999; Ramer & Smith, 1993; Smith, 1996). There have been reports of poor quality control in some recycled plastic posts with large voids, inconsistent surfaces, and

undissolved pieces of plastic (Smith, 1996). A study conducted by the Oregon Department of Transportation concluded that recycled plastic posts were not a reasonable alternative to wooden and metal posts because of several problems, including fading and bowing of the posts (Hunt, 1993). In addition, the plastic posts were significantly heavier and required additional hardware to prevent cracking when bolts were tightened. The increased weight of the plastic product (up to 35 percent heavier) has safety implications for employees (Heidenreich, 1997; Hunt, 1993).

The technical evaluation for recycled plastic lumber yielded a score of 3.

Technical Evaluation Score Sheet for Recycled Plastic Lumber	
<p>1. Is the alternative safe for employees and the general public? 2 – decreases health and safety risk 1 – does not affect health and safety risk 0 – increases health and safety risk</p>	Score: 0
<p>2. Will product or service quality be maintained? 2 – increases product or service quality 1 – does not affect product or service quality 0 – decreases product or service quality</p>	Score: 1
<p>3. Is the new product or process compatible with other operations that are not changing? 2 – completely compatible with other operations 1 – compatible with only minor modifications 0 – compatible only after major modifications</p>	Score: 1
<p>4. How long will it take to implement the option? 2 – implementation will take less than 6 months 1 – implementation will take 6 to 18 months 0 – implementation will take more than 18 months</p>	Score: 1
TOTAL SCORE: 3	

Environmental Evaluation

Normally, an option receiving a score below 4 in the technical area would be eliminated from consideration. However, the environmental evaluation was conducted for this study because it served as a test for the protocol.

Disposal of recycled plastic lumber is much easier and has less impact on the environment than disposal of treated lumber. Most suppliers will buy back damaged or unwanted material and recycle it, essentially eliminating the waste stream (Amirkhanian, 1999; Hunt, 1995). The use of recycled plastic lumber has an even greater effect on waste streams outside VDOT since it results in a reduction in the use of pressure treatment chemicals such as copper, chromium, and arsenic. In addition, not only does the switch from recycled plastic lumber reduce the natural resources (in this case, trees) consumed, it also provides an important market for the use of recycled products.

The environmental evaluation for recycled plastic lumber yielded a score of 19.

Environmental Evaluation Score Sheet for Recycled Plastic Lumber

1. Is the overall quantity of waste reduced:	
• for VDOT?	
3 – quantity of waste is significantly reduced	
2 – quantity of waste is reduced	
1 – no effect on quantity of waste	
0 – increases quantity of waste	
	Score: 3
• outside VDOT?	
3 – quantity of waste is significantly reduced	
2 – quantity of waste is reduced	
1 – no effect on quantity of waste	
0 – increases quantity of waste	
	Score: 3
2. Is the toxicity of waste produced reduced?	
3 – toxicity of waste is significantly reduced	
2 – toxicity of waste is reduced	
1 – no effect on toxicity of waste	
0 – increases toxicity of waste	
	Score: 2
3. Is there a transfer of waste to other media?	
3 – no transfer of waste to other media	
2 – transfer of waste is minimal	
1 – transfer of waste is smaller than overall reduction	
0 – transfer of waste is greater than overall reduction	
	Score: 2
4. Is there a reduction in energy/natural resource consumption?	
3 – significant reduction in consumption	
2 – reduction in consumption	
1 – no change in consumption	
0 – increase in consumption	
	Score: 3
5. Is the alternative acceptable to regulators?	
3 – directly enhances regulatory compliance	
2 – indirectly enhances regulatory compliance	
1 – no effect on regulatory compliance	
0 – has a negative effect on regulatory compliance	
	Score: 2
6. What is the public perception of the alternative?	
3 – significantly improves public image	
2 – improves public image	
1 – little or no effect on public image	
0 – lowers public image	
	Score: 2
7. Will long-term liability be reduced?	
3 – significantly reduces long-term liability	
2 – reduces long-term liability	
1 – little or no effect on long-term liability	
0 – may increase long-term liability	
	Score: 2
TOTAL SCORE: 19	

Scoring Calculation

It is recommended that the weighting for this P2 alternative deviate slightly from that recommended by the protocol. Economic data are highly variable, and the emphasis placed on this score should be reduced. The scores for safety and service quality are extremely important in the implementation of this new product. The emphasis on scores related to waste quantity is also increased because of the potential impact this alternative would have on waste production. The recommended weightings yielded a final score for recycled plastic lumber of 1.8.

Final Score Sheet for Recycled Plastic Lumber			
Area	Area Score	Weighting Value	Total Score
Economic Evaluation	1	5	5
Technical Evaluation			
safety	0	8	0
product/service quality	1	8	8
compatibility	1	6	6
implementation time	1	5	5
Environmental Evaluation			
waste quantity in VDOT	3	8	24
waste quantity out of VDOT	3	10	30
toxicity	2	5	10
media transfer	2	5	10
energy consumption	3	5	15
regulatory acceptance	2	10	20
public perception	2	6	12
long-term liability	2	5	10
Total	23	86	155
Final Score (total score/weighting value) = (155/86) = 1.8			

Implementation Recommendation

Although the final score (1.8) for the use of recycled plastic lumber to replace treated lumber posts was well above the implementation threshold of 1.3, it is recommended that the implementation of this P2 option be postponed because of the technical problems related to product quality and consistency. Because of the many documented benefits related to recycled plastic lumber and because of the anticipated improvements in quality control, it is also recommended that this opportunity be evaluated again in 18 to 24 months.

Lead Acid Battery Extenders

Description of Alternative

Lead acid batteries are used extensively by VDOT, supplying electrical power to nearly all motorized equipment and vehicles. The average 12-V lead acid battery consists of six

electrochemical cells, each delivering 2 V. In its simplest form, the lead acid battery consists of two lead grids; a layer of lead oxide, PbO_2 , covers one of the grids. The two electrodes are immersed in sulfuric acid solution and contained inside the battery wall. When the battery is discharged, an oxidation reaction occurs at the anode or pure lead grid. A layer of solid lead sulfate, $PbSO_4$, becomes plated onto the electrode. The PbO_2 on the other lead grid acting as the cathode becomes reduced. Two electrons are needed for this half-reaction, and they come from the half-reaction previously described. They go through the electrical system of the vehicle or equipment, thereby providing electricity (Manahan, 1993). The basic technology of lead acid batteries has not changed for nearly 50 years. Immediately following the initial immersion of the battery cells into the sulfuric acid solution, sulfation begins to take place on the plates, increasing resistance to the previously described chemical process. Ultimately, this reduces the life of the battery.

A number of technologies are available to increase the useful life of lead acid batteries by reducing or reversing the sulfation of the lead anodes and cathodes. Reducing sulfation by way of pulse technology shows great promise in extending the life of lead acid batteries. This technology works by emitting a pulsating DC into the battery, removing the sulfates from the plates and back into the sulfuric acid solution. The life of up to 80 percent of all batteries that are replaced each year could be extended (PulseTech, 2000).

Data Collection

A wide variety of material was available on the Internet describing various lead acid battery extenders and their specific advantages. Unfortunately, most of this information was available from vendors of the various products and not from independent sources. Virtually no information was available regarding these extenders in the scientific and transportation journals examined. Some anecdotal information was gathered. Additional information was gathered from VDOT's Equipment and Fleet Management divisions on the number and costs of batteries purchased annually.

Economic Evaluation

It was estimated from VDOT sources that between 3,500 and 6,000 lead acid batteries are purchased each year and range in price from \$30 to \$75. This takes into account batteries purchased by both the Equipment Division and the Fleet Management Division. Costs of the lead acid battery extenders varied from \$59 to \$249. The least expensive units are designed to be used in conjunction with normal 12-V automotive batteries. Those designed for heavy duty batteries, such as those found on forklifts, are more expensive. Claims regarding increased service life ranged from 100 to 400 percent (PulseTech, 2000). If one assumes that the average price of a 60-month automotive battery is \$50 and that of an extender is \$60, if a single extender unit could serve a minimum of two batteries, the life of the battery would need to be extended 36 months to reach the breakeven point. Both of these assumptions (one extender serving two batteries and the life of the batteries being extended 36 months) are deliberately conservative. Based on this limited information, it appears that the battery extenders are economically feasible.

The economic evaluation for lead battery acid extenders yielded a score of 1.

Technical Evaluation

From the limited technical information available, it appears that the battery extenders are safe and reliable. The basic concept on which the technology is based is sound. Again, vendors of the products provided all information available. A single study found on the use of lead acid battery extenders was requested but was not available in time for inclusion in this report.

The technical evaluation for lead battery acid extenders yielded a score of 6.

Technical Evaluation Score Sheet for Lead Battery Acid Extenders	
1. Is the alternative safe for employees and the general public? 2 – decreases health and safety risk 1 – does not affect health and safety risk 0 – increases health and safety risk	Score: 1
2. Will product or service quality be maintained? 2 – increases product or service quality 1 – does not affect product or service quality 0 – decreases product or service quality	Score: 2
3. Is the new product or process compatible with other operations that are not changing? 2 – completely compatible with other operations 1 – compatible with only minor modifications 0 – compatible only after major modifications	Score: 1
4. How long will it take to implement the option? 2 – implementation will take less than 6 months 1 – implementation will take 6 to 18 months 0 – implementation will take more than 18 months	Score: 2
TOTAL SCORE: 6	

Environmental Evaluation

Assuming the lead acid battery extenders are indeed technically feasible, there are numerous environmental benefits of using these products. By reducing the turnover rate of the used batteries, VDOT reduces the number of batteries it must remove from vehicles and equipment, store, and transport to a recycling facility. In turn, there is a reduction in the likelihood of spills and contamination related to the storage and transportation. In addition, not only is VDOT's waste stream and liability reduced, the waste stream outside VDOT is also reduced.

The environmental evaluation for lead battery acid extenders yielded a score of 14.

Environmental Evaluation Score Sheet for Lead Battery Acid Extenders

- | | |
|---|------------------------|
| <p>1. Is the overall quantity of waste reduced:</p> <ul style="list-style-type: none">• for VDOT?<ul style="list-style-type: none">3 – quantity of waste is significantly reduced2 – quantity of waste is reduced1 – no effect on quantity of waste0 – increases quantity of waste
• outside VDOT?<ul style="list-style-type: none">3 – quantity of waste is significantly reduced2 – quantity of waste is reduced1 – no effect on quantity of waste0 – increases quantity of waste | <p>Score: 2</p> |
| <p>2. Is the toxicity of waste produced reduced?</p> <ul style="list-style-type: none">3 – toxicity of waste is significantly reduced2 – toxicity of waste is reduced1 – no effect on toxicity of waste0 – increases toxicity of waste | <p>Score: 1</p> |
| <p>3. Is there a transfer of waste to other media?</p> <ul style="list-style-type: none">3 – no transfer of waste to other media2 – transfer of waste is minimal1 – transfer of waste is smaller than overall reduction0 – transfer of waste is greater than overall reduction | <p>Score: 3</p> |
| <p>4. Is there a reduction in energy/natural resource consumption?</p> <ul style="list-style-type: none">3 – significant reduction in consumption2 – reduction in consumption1 – no change in consumption0 – increase in consumption | <p>Score: 2</p> |
| <p>5. Is the alternative acceptable to regulators?</p> <ul style="list-style-type: none">3 – directly enhances regulatory compliance2 – indirectly enhances regulatory compliance1 – no effect on regulatory compliance0 – has a negative effect on regulatory compliance | <p>Score: 1</p> |
| <p>6. What is the public perception of the alternative?</p> <ul style="list-style-type: none">3 – significantly improves public image2 – improves public image1 – little or no effect on public image0 – lowers public image | <p>Score: 1</p> |
| <p>7. Will long-term liability be reduced?</p> <ul style="list-style-type: none">3 – significantly reduces long-term liability2 – reduces long-term liability1 – little or no effect on long-term liability0 – may increase long-term liability | <p>Score: 2</p> |
| <p>TOTAL SCORE: 14</p> | |

Scoring Calculation

It is recommended that the weighting for this P2 alternative follow that recommended by the protocol.

The final score for lead battery acid extenders was 1.5.

Final Score Sheet for Lead Battery Acid Extenders			
Area	Area Score	Weighting Value	Total Score
Economic Evaluation	1	8	8
Technical Evaluation			
safety	1	8	8
product/service quality	2	7	14
compatibility	1	6	6
implementation time	2	5	10
Environmental Evaluation			
waste quantity in VDOT	2	6	12
waste quantity out of VDOT	2	6	12
toxicity	1	5	5
media transfer	3	5	15
energy consumption	2	5	10
regulatory acceptance	1	10	10
public perception	1	6	6
long-term liability	2	5	10
Total	21	82	126
Final Score (total score/weighting value) = (126/82) = 1.5			

Implementation Recommendation

Lead acid battery extenders should be considered for use by VDOT. Because the majority of information used in this analysis was not obtained from unbiased sources, it is recommended that a few of the more inexpensive units be purchased and used on a trial basis and that the final results be documented. Based on the findings of this pilot, more widespread use should be considered.

CONCLUSIONS

- Both the private sector and federal agencies have developed many criteria and methods to evaluate P2 opportunities.
- No single method or protocol identified in the literature is directly applicable to VDOT, as none was developed specifically for state departments of transportation.

- The evaluation protocol developed as a part of this study appears to be a useful tool for VDOT to use when determining what opportunities to implement as part of its agency-wide Pollution Prevention Plan.
- Aqueous parts washers are economically and environmentally advantageous when compared to solvent-based parts washers.
- Recycled plastic lumber, although environmentally beneficial, suffers from quality control problems, making it technically inferior to treated lumber when used as signposts.
- Various types of lead acid battery extenders show great promise in significantly extending battery life, but little technical data are available other than those provided by product vendors.

RECOMMENDATIONS

1. *VDOT should use a P2 evaluation process similar to that outlined in this study.* No single process will be applicable to all P2 opportunities that arise, but a simple, consistent method needs to be used to evaluate the majority of the options that VDOT has identified. This will help ensure that more options are considered for implementation and that they are evaluated fairly and uniformly.
2. *VDOT should begin phasing out solvent-based parts washers by replacing them with aqueous-based parts washers.* Several VDOT districts have begun to use these washers on an experimental basis, but a more concerted effort should be made to purchase the aqueous-based washers to reduce the waste stream and liability related to parts washing.
3. *VDOT should delay any plans to replace treated lumber signposts with recycled plastic lumber signposts.* Although there are clear environmental advantages to using recycled plastic lumber, quality control concerns need to be addressed further. This P2 option should be evaluated again in 18 to 24 months.
4. *VDOT should begin using some of the lead acid battery extenders now available on the market.* This should be done only on a trial basis until additional information on the success of the technology is available from users. This may be accomplished by having one district experiment with the technology on a pilot basis.

REFERENCES

- Adams, M. & Larson, M.J. (February 1995). Evaporative Technology for Waste Stream Reduction in Aqueous Parts Washer. In *Diesel Progress North American*. Diesel & Gas Turbine Publications, Solana Beach, CA.

- Amirkhanian, S.N. (1999). *A Laboratory and Field Evaluation of the Use of Waste Materials in Highway Construction*. South Carolina Department of Transportation, Columbia.
- Aviva, S. (1998). *Operational Test Report for Field Demonstration Testing of the Mobile Alkaline Cleaner Recycler*. (Report No. TR-2087-ENV). Naval Facilities Engineering Service Center, Port Hueneme, CA.
- Boyd, J. (1998). *Searching for the Profit in Pollution Prevention: Case Studies in the Corporate Evaluation of Environmental Opportunities*. (Discussion Paper 98-30). Resources for the Future, Washington, DC.
- Hag-Elsafi, O.; Elwell, D.J.; Glath, G.; & Hiris, M. (1999). Noise Barriers Using Recycled-Plastic Lumber. *Transportation Research Record No. 1670*. Transportation Research Board, Washington, DC.
- Hanson, M.J., Aden, T.S., & Bevelheimer, S.J. (1997). *Evaluation of Automatic Aqueous Parts Washers*. (Technical Report No. 98/16). U.S. Army Corps of Engineers, Construction Engineering Research Laboratories, Champaign, IL.
- Heidenreich, W. (1997). *Recycled Plastics in Highway Construction and Maintenance, Final Report*. (Report No. OR-RD-98-02). Oregon Department of Transportation, Policy/Research Section, Salem.
- Hunt, E.A. (1993). *Recycled Plastics in Highway Construction and Maintenance, Construction Report*. Oregon Department of Transportation, Salem.
- Hunt, E.A. (1995). Recycled Plastic Mixed Blessing for Appurtenances, Oregon DOT Finds. *Roads & Bridges*, 33(4), 68-71.
- Kennedy, M.L. (1994). Getting to the Bottom Line: How Total Cost Assessment Shows the Real Cost of Solvent Substitution. *Pollution Prevention Review*, 4(2), 155-164.
- Lowell, D.D. (1995). *Synthesis of Transit Practice 9: Waste Control Practices at Bus Maintenance Facilities*. Transportation Research Board, Washington, DC.
- Manahan, S.E. (1993). *Fundamentals of Environmental Chemistry*. Lewis Publishers, New York.
- Ministry of Environment and Energy. (1993). *Pollution Prevention Planning and Guidance Document and Workbook*. (ISBN 0-7778-3963-6). Ontario, Canada.
- Pelley, J. (1997). Environmental R and D Shifts to Pollution Prevention. *Environmental Science and Technology*, 31(3), 138A-141A.
- Phoenix. (March 2000). www.plasticlumberyard.com/plasticlumber.htm.

- Pojasek, R.B. (1997). Practical Pollution Prevention: Understanding a Process with Process Mapping. In *Pollution Prevention Review*. John Wiley & Sons, Inc., New York.
- Pacific Northwest Pollution Prevention Resource Center. (1996). *Aqueous Cleaning Technology Review*. Seattle.
- Presley, M.K. & Finney, J.W. (1995). *EXTRAN™ A New Membrane System for Recycling Aqueous Parts Washing Fluid*. (Technical Paper Series 950244). Society of Automotive Engineers, Inc., Warrendale, PA.
- PulseTech. (April 2000). www.pulsetech.net.
- Ramer, R.M., & Smith, L.L. (1993). Recycled Plastics for Highway Agencies. In *Transportation Research Record 1345*. Transportation Research Board, Washington, DC.
- Rowney, M.J. et al. (1992). Impingement: The Key to Effective Aqueous Cleaning. In *Proceedings of the 79th AESF Annual Technical Conference SUR/FIN '92*. American Electroplaters and Surface Finishers Society Press, Orlando.
- Saadeghvaziri, M.A. & Macbain, K.M. (1999). *Recycled Plastics for Highway Appurtenances*. (Report No. FHWA/NJ-99-013-7630). New Jersey Department of Transportation, Trenton.
- Schroeder, R.L. (1994). The Use of Recycled Materials in Highway Construction. *Public Roads*, 58 (2), 322-341.
- Smith, L.L. (1996). Wasting No Time: Florida's History of Successful Recycling for Transportation From Refuse to Reuse: Recycling and Reuse of Waste Materials and By-Products in Transportation Infrastructure. *TR News*, 184, 4-7.
- U.S. Army Center for Health Promotion and Preventive Medicine. (1997a). *Fleet Motor Pool Pollution Prevention Guide*. (USACHPPM Project Number 37-EF-4823-96). Aberdeen Proving Ground, MD.
- U.S. Army Center for Health Promotion and Preventive Medicine. (1997b). *Tactical Motor Pool Pollution Prevention Guide*. (USACHPPM Project Number 37-EF-4823-96). Aberdeen Proving Ground, MD.
- U.S. Department of Energy. (1993a). *Model Pollution Prevention Opportunity Assessment Guidance*. Assistant Secretary for Defense Programs, Washington, DC.
- U.S. Department of Energy. (1993b). *Prioritization of Pollution Prevention Options Using a Value Engineering Approach*. Assistant Secretary for Defense Programs, Washington, DC.

U.S. Environmental Protection Agency. (1992). *Total Cost Assessment: Accelerating Industrial Pollution Prevention through Innovative Project Financial Analysis*. (Report No. EPA/741/R-92/002). Office of Pollution Prevention and Toxics, Washington, DC.

U.S. Environmental Protection Agency. (1994). *Federal Facility Pollution Prevention Planning Guide*. (Report No. EPA-300-B-94-013). Office of Enforcement and Compliance Assurance, Washington, DC.

U.S. Environmental Protection Agency. (1995). *Federal Facility Pollution Prevention Project Analysis: A Primer for Applying Life Cycle and Total Cost Assessment Concepts*. Office of Enforcement and Compliance Assurance; Planning, Prevention, and Compliance Division; Federal Facilities Enforcement Office, Washington, DC.

APPENDIX

VDOT'S P2 OPPORTUNITY LIST

Power down Sun Workstations on weekends; turn off monitors when not in use
Limit copies of county and state maps; donate excess to schools
More accessible recycling containers
Evaluate pilot wash water recycling units for maintenance facilities
Develop system for cataloging and utilizing product warranties
Improve quality of state contract items through pass/fail ratings scheme
Require vendors (through IFB terms) to re-use fuel commodity containers
Develop and implement 2-sided copy policy
Mixed paper recycling contract
Glass and aluminum recycling contract
Capital Outlay construction bids and plans on Internet
Purchase/deliver traffic paint on "as need" or "satellite" distribution basis
Explore recycling of latex paint waste
Evaluate alternative paint transfer methods from drum to spray truck
Evaluate returnable/ refillable paint drums
Use non-petroleum asphalt/tar removers vs. petroleum
Develop techniques to remove suspended solids for recycling solvents
Require roadside vegetation management contractors to supply all herbicides
Implement fluorescent lamp recycling at CESOG facilities
Purchase low-mercury fluorescent lamps
Explore use of synthetic oils for equipment and vehicles
Expand used oil filter recycling program
Use "regeneratable" antifreeze
Explore use of spray gun washing system (Safety Kleen)
Incorporate P2 benefits in New Product Review rating process
Adopt EPA "Green Lights" standards for new facilities
Establish policy for turning off computers at night
Eliminate use of "cutback asphalt" adjacent to waterways or storm sewer inlets
Recycle aerosol cans
Change VDOT spec to require 100 percent post-consumer mulch
Explore use of oil evacuation system for oil changes
Develop internal material/equipment exchange listing
Implement reusable/refillable pesticide containers (currently pilot project in Salem District)
Designate diesel drainage receptacle for capturing diesel line bleed and reuse fuel
Explore use of engine oil analysis for determining oil change intervals for large equipment
Explore use of private vehicle painting contractor
Replace vehicle paint sprayers with low-VOC equipment
Purchase 1-gallon oil-based paint on "as need" basis
Distribute only approved pesticides and require complete use
Recycle asphalt/concrete samples in producers' RAP stockpile
Explore anti-icing technology for maximizing use of de-icing chemicals
Explore use of digitized signatures

Explore procurement of solar-powered message signs
Contract with firm to refill printer cartridges
Purchase bicycles for district complexes
Install vapor-recovery equipment on fuel pumps
Encourage carpools for field visits or meetings
Encourage teleconferencing
Explore videoconferencing capabilities
Change policy to allow plans to be submitted electronically
Solicit bids for scrap wood in all districts
Explore the use of additives for extending the life of lead acid batteries
Reduce the size (scale) of plan sheets for draft and intermediate designs (i.e., 1/2 or 3/4 scale)
Specify the use of vegetable-based oil for spreader lubrication
Eliminate solvent extraction method for asphalt testing
Conduct more pedestrian and bicycle counts during transportation planning and provide appropriate facilities
Require large traffic generators (shopping centers, etc.) to incorporate public transportation into site plans; amend VDOT entrance permit requirements
Change toll rate structures to encourage ride sharing
Establish and fund "Commuter Bike Routes"
Review and optimize signal timing at isolated intersections
Eliminate use of multicolored paper
Purchase only 4-cycle engine products when available
Eliminate solvent-based paints for pavement marking
Implement policy for turning off appliances on off-hours
Expand use of "tote tanks" for traffic paint
Recycle cleaner used in silk screening
Use motion sensor lights in infrequently used areas
Explore the use of recycled plastic lumber to replace chemically treated wood
Use overlays, UV-cured inks, or pre-printed sheeting for signing to replace solvent-based inks
Establish corrugated cardboard recycling contract
Expand the use of thermoplastic versus traffic paint
Develop Waste Management Procedure Manuals for remaining eight districts
Explore use of aqueous parts washers
Eliminate use of low-flash solvent parts washers (i.e., implement consistent use statewide)
Purchase additional hazardous waste/pesticides safe storage units
Implement first-in/first-out computerized inventory policy
Rebuildable parts: give/sell to remanufacturer