A LIFE CYCLE ANALYSIS SYSTEM TO SUPPORT D&D, POLLUTION PREVENTION, AND ASSET RECOVERY

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ABSTRACT

This paper describes a life cycle analysis system (LCAS) developed to support U.S. Department of Energy (DOE) decision-making regarding deactivation and decommissioning (D&D), pollution prevention (P2), and asset recovery, and its deployment to analyze the disposition of facilities and capital assets. Originally developed for use at the Oak Ridge East Tennessee Technology Park, this approach has been refined through application at Ohio Operations Office sites and is now being deployed at a number of DOE sites. Programs such as National Metals Recycle, the D&D Focus Area, P2, and Asset Utilization are successfully using the system to make better decisions resulting in lower cost to the taxpayer and improved environmental quality.

The LCAS consists of a user-friendly, cost-effective, and analytically-sound decision-aiding process and a complementary suite of automated tools to handle data administration and multiple criteria life cycle analysis (LCA). LCA is a systematic and comprehensive process for identifying, assessing, and comparing alternatives for D&D, P2, and asset recovery at government sites, and for selecting and documenting a preferred alternative. An LCA includes all of the impacts (benefits and costs) that result from a course of action over the entire period of time affected by the action. The system also includes visualizations that aid communication and help make decision-making transparent. The LCAS has three major components related to data collection, decision alternative assessment, and making the decisions. Each component is discussed in-depth using the example of deployment of the LCAS to support asset recovery.

INTRODUCTION

The Center for Life Cycle Analysis at Oak Ridge National Laboratory has developed a life cycle analysis system (LCAS) to support U.S. Department of Energy (DOE) decision-making regarding deactivation and decommissioning (D&D), pollution prevention (P2), and asset recovery. More generally, the LCAS allows DOE to better understand and exploit recycling and reindustrialization opportunities that exist throughout the DOE complex. The LCAS has been used to benefit DOE's National Metals Recycle, D&D, P2, and Asset Utilization programs.

Originally developed for use at the Oak Ridge East Tennessee Technology Park (ETTP), the LCAS was refined through application at Ohio Operations Office sites and has now been successfully implemented at a number of DOE sites.[1] In one of the first applications of life cycle analysis (LCA), DOE relied on a detailed LCA to decide to recycle more than 100,000 tons of scrap metal at the ETTP rather than dispose of it. This decision alone prevented about 5,000 trucks of metal traveling across the country from Tennessee to Nevada

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to dispose of the metal. The LCAS has also been used to support decisions on disposition of structural steel and copper at the Fernald Environmental Management Project, and concrete and soil from the West Valley Demonstration Project. The National Metals Recycle Program has successfully used the LCAS to leverage Cold War legacy equipment and materials to accelerate cleanups and promote reindustrialization activities at DOE sites. Specifically, the program has used LCA to support recycle of scrap metal at the Weldon Spring Site and the Oak Ridge National Laboratory Tower Shielding Facility, and reuse of drums, B-25 boxes, and metal pallets. As these examples demonstrate, DOE has successfully used the LCAS to produce better decisions resulting in lower costs to the taxpayer and improved environmental quality.

The motivation behind the LCAS is to help DOE make better decisions by helping decision-makers to understand all impacts of decisions, by making the decision-making process transparent, and by facilitating substantive involvement in the decision-making process. Our approach to LCA differs from other approaches by taking into consideration all the factors important to stakeholders. In addition to life cycle cost, we consider health and safety impacts, environmental impacts, programmatic impacts, and other factors. Consideration of these impacts need not be extensive or excessively burdensome; it should be commensurate with the potential benefits. However, the simple process of considering each of the alternatives on each of the relevant attributes will ensure that all factors important to the decision have been considered and will help avoid unintended consequences.

In the DOE complex, as well as in our personal lives, poor decisions are often the result of focusing on a single, particularly salient objective (e.g., minimizing near-term cost), without fully considering other possible impacts of our actions. As a result, for example, P2 initiatives that would payback the initial investment many times over, as well as produce environmental benefits, have gone unfunded. In addition, an LCA does not consider the color of money. For example, many P2 proposals will incur an additional investment by one DOE program, only to produce an even larger savings in another DOE program (as well as significant environmental benefits). By looking at the total benefit to the government, LCA seeks to ensure that such beneficial projects will be funded. Use of the LCAS will help to ensure that we do not miss these cost-saving opportunities in the future and that we do not inadvertently create tomorrow's environmental challenges.

Often a detailed LCA will suggest a different decision from a more limited investigation. For example, some DOE sites were crushing contaminated drums in order to reduce volume. Using LCA, the National Metals Recycle program has developed a cost-effective method of reuse of drums – however drums that have been crushed cannot be cost-effectively reused and must be disposed of. So the old decision rule "crush drums" has been replaced with the new decision rule "reuse drums," which saves the government money. As a second example, some sites were imploding buildings. But once the building is imploded, the metal becomes so mangled that it is too costly to decontaminate, and it must be disposed of. Dismantlement of the building, while having a larger initial cost, would have allowed for cost-effective reuse. A third example concerns the ETTP K770 scrap yard, a pile of scrap metal located in the middle of prime commercial real estate. The pile had not been addressed because of the cost of doing so – but allowing the pile to remain has significantly delayed the reindustrialization of a large tract of prime real estate. An LCA showed the reindustrialization benefits of removal of the pile and identified recycling strategies to make removal of the pile cost-effective.

There are several other advantages to using the LCAS. The framework aids communication in public meetings by helping focus discussions, and facilitates the process of gaining substantive public input in decision-making. Further, rather than decisions being made without the benefit of all stakeholders and all relevant facts being assessed, we seek to make the decision-making process transparent. The LCA approach helps to make decisions understandable and defensible by making clear the data and reasoning underlying

the decision. The LCAS provides a systematic and standardized process so that cross-site/program comparisons are possible. Finally, the decision-aiding framework is robust. It can be tailored to meet site and project conditions and can easily be applied to D&D, P2, and asset recovery projects throughout the DOE complex.

The LCAS consists of a user-friendly, cost-effective, and analytically-sound decision-aiding process and a complementary suite of automated tools to handle data administration and multiple criteria LCA. LCA is a systematic and comprehensive process for identifying, assessing, and comparing alternatives for D&D, P2, and asset recovery at government sites, and for selecting and documenting a preferred alternative. An LCA includes all of the impacts (benefits and costs) that result from a course of action over the entire period of time affected by the action. The LCAS also includes a visualization component that has been proven to aid communication and stakeholder involvement in the decision-making process.

The LCAS has three major components related to data collection, decision alternative assessment, and making the decisions. This paper describes the LCAS and its deployment to analyze the disposition of facilities and capital assets. The balance of this paper describes the basics of LCA, the prototype processes and methods developed to take LCA into the field to support unused assets decision-making, and recounts initial experiences with the prototype. The paper concludes with several observations on the future of this work.

LIFE CYCLE ANALYSIS BASICS

The ORNL LCA approach has its foundations in the field of decision analysis.[2] Fundamentally, the goals of decision analysis are, simply stated, to help people: understand the problems they face; construct decision alternatives (options) to solve the problems; specify criteria (attributes) over which to judge decision alternatives; and make trade-offs among decision alternatives and criteria to arrive at reasonable and defensible decisions. The LCA approach considers each of the alternatives on each of the relevant attributes in order to ensure that all effects are considered when making decisions and reduce the likelihood of unintended and unforeseen consequences.

DOE program managers do not have the time and the resources to conduct exhaustive data collection and assessment efforts to evaluate all potential alternatives over all potential decision criteria related to the disposition of facilities and capital assets. They need a practical and streamlined yet analytically structured approach to this class of decision problems. Specifically, the decision-aiding approach itself needs to meet these criteria:

- *Cost-Effectiveness*. Data needed for the LCAS must be straightforward to collect and the collection efforts must not require undue time and money. The process must be systematic and easily implemented;
- *Comprehensiveness of Decision Factors*. The LCAS needs to encompass a range of decision factors to allow decision makers to understand the complex context of their decisions;
- *Defensible Results*. The outputs of the system must be rigorous and replicable; and
- *Standardization*. The approach must be standardized so that cross site/program comparisons are possible.

The Center for Life Cycle Analysis at Oak Ridge National Laboratory has developed an LCA approach that meets these criteria.

Many factors influence D&D, P2, and asset recovery decisions. Six decision criteria which have been seen as important in many similar situations are:

- life cycle cost;
- environmental impacts;
- public and worker health and safety impacts;
- pollution prevention;
- programmatic impacts; and
- reindustrialization impacts.

Ideally, all possible alternatives would be evaluated against these decision criteria and the "optimum" alternative identified. The real world complicates the implementation of this simple model in many ways. Oftentimes, time and money constraints limit the amount of data that can be collected for input into a decision analysis, the number of alternatives that can be considered, and the sophistication of the models used to evaluate alternatives over decision criteria. Political situations surrounding decision contexts often influence how (and maybe even whether) the results of decision analyses are ultimately used.

The approach presented below addresses these major problems. First, the approach is as streamlined as possible. Only the minimum amount of information needed to make reasonable and defensible decisions is to be collected. Initially, only simple spreadsheet tools are envisioned to support quantitative analyses. Other decision inputs will be based on the sound judgments of experts, decision makers, and relevant stakeholders. Second, the approach makes as transparent as possible the values people place on various evaluation criteria.[3] This fosters involvement of multiple stakeholders and communication of their values to other stakeholders. Given that public participation is becoming more important in all aspects of public environmental decision making, this is an especially important aspect of this approach.

DEPLOYMENT TO SUPPORT ASSET RECOVERY

The decision problem faced by many DOE program managers is what to do with facilities and capital assets. As DOE programs have changed over the past several years, many buildings and capital assets once central to the nation's Cold War effort are no longer needed. Simply ignoring these assets is not an option since many are contaminated with radiological and chemical hazards. Thus, DOE must consider the option of disposing of these assets as part of its environmental remediation responsibilities. However, many of the assets may have some value to parties other than DOE. For example, many of the buildings contain metals that can be sold on the scrap metal market for recycle, either as-is or after some decontamination. Some of the capital equipment could possibly be refurbished and reused by other government programs or sold to private sector buyers for re-use. Even the buildings could be cleaned-up (to an appropriate degree) and then renovated and re-used by private sector companies. This last alternative could help develop private sector economic opportunities in communities that host DOE sites. Thus, for many facilities and capital assets at DOE sites, program managers face several alternatives, which generically are disposal, recycle, and reuse.

PROTOTYPE PROCESSES AND METHODS

The LCAS has three components. The first relates to data collection and provides guidance to DOE-sites on what data need to be collected and how to collect the data. The second addresses the task of assessing decision alternatives over decision criteria. The third addresses the problem of choosing among a set of decision alternatives which may contain no clear-cut winner. This section discusses each component in turn using asset recovery to demonstrate the process.

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Data Collection

The data collection component of the LCAS has four steps relating to: project team composition, data acquisition sheets, identifying data sources, and walk-around asset assessment exercises. Each step is described in more detail.

Step 1. Assemble Asset Utilization Project Team

Disposition of unused assets decision making requires a wide range of expertise, from knowledge of disposal methods and laws to prices for scrap metals of different kinds, from what industries might use various pieces of equipment to the needs of local industries for different kinds of buildings (and associated equipment). Thus, as a first step, a team of personnel with the required expertise must be identified that is capable of guiding the process from origination of the disposition alternatives through review and approval by all affected organizations. Project team members may include personnel from the following departments and disciplines: property management; environmental compliance; operations; legal; engineering; materials control; health and safety; pollution prevention; waste management; environmental restoration; and building engineer. To assist the DOE sites, a worksheet can be prepared that would identify potential Asset Utilization Project Team Members. This worksheet would list the department, name, telephone number, fax number, e-mail address, of each of the personnel involved in the process.

Step 2. Develop and/or Tailor Data Acquisition Sheets and Checklists

This step entails developing information gathering sheets and checklists. The purpose of the sheets is to ensure that all information that is potentially relevant to the ultimate decision about an unused asset (e.g., a building or a piece of capital equipment) is collected, or at least attempted to be collected. Three types of sheets have been developed: a building assessment checklist, a capital equipment asset checklist, and building status sheet. These sheets are intended to be generic and useable by all DOE sites for all types of buildings and assets. These sheets should be standardized across the DOE sites to allow common database structure and for DOE Headquarters programs to conduct DOE-wide assessments and analyses on the status of unused assets. However, the sites can add to these sheets as appropriate. Each sheet is now discussed.

Building Assessment Checklist

The purpose of this checklist is to collect all relevant information about buildings to support disposal, recycle, and reuse decisions. The following general information need to be collected:

- General Information (e.g., location, age, special entry requirements);
- Physical Description (e.g., office space, manufacturing space, storage space, laboratory space, outside/adjacent space);
- Utilities (e.g., environmental controls, natural gas, lighting, water, fire suppression system, computer wiring);
- Contamination (e.g., types and quantities of contamination),
- Disposition Costs (e.g., disposition alternatives, baseline cost estimate, reuse value); and
- Other Attribute Items (e.g., economic development attributes — rail access, barge access, programmatic and schedule impacts, pollution prevention, worker safety).

An extensive buildings assessment checklist has been prepared that contains all these categories of information. It needs to be mentioned that not all items in the checklist will apply to every unused building at every DOE site. The decision alternative assessment approach does not require exhaustive information,

just useful information. Additionally, people responsible for filling out the checklist will be instructed not to be dissuaded if some of the information is difficult to determine. Fuzzy answers are acceptable. For example, the answer to D&D cost may be "very high" or "negligible". This type of "binning", though imprecise, will still provide valuable information to decision-makers. The bottom line is that questions will not be excluded from a checklist even if it may be quite difficult to determine the answer precisely.

Capital Equipment Asset Checklist

The purpose of this checklist is to collect all relevant information about capital equipment assets to support disposal, recycle, and reuse decisions. The following general information need to be collected:

- General Information (e.g., location, number being considered);
- Asset Physical Description (e.g., generic name {pump, crane}, material type {stainless steel, aluminum, etc.}, age, weight, volume, condition);
- Cost (e.g., reuse value, scrap value); and
- Contamination and Disposition Information (e.g., types of contaminants and levels, decontamination methods and costs).

Building Status Sheet

The purpose of this checklist is to collect all relevant information about buildings that might appear on an industrial properties multiple listings source (MLS). The following general information need to be collected:

- General Description (e.g., textual description of the building, what was used for in the past, its condition, and what it could be used for in the future);
- Physical Description (e.g., location, age, dimensions, square footage, utilities, etc.);
- Office Area (e.g., size, square footage, offices, conference rooms, computer and telephone wiring); and
- Manufacturing Areas (e.g., size, square footage, overhead clearance, lighting, ventilation, bridge cranes, environmental controls).

Step 3. Identify and Use Existing Data Sources

This step begins the process of collecting information to fill in the three sheets described above. The natural first place to start is to identify and assemble existing data sources. Following are types of documents that probably exist at every DOE site (although may not exist for every building) that the project team should attempt to assemble: Project Baseline Summary; end-use plan; Basis for Interim Operations; Safety Analysis Report; Waste Management Plan; Characterization Reports; Remedial Investigation/Feasibility Study; and other baseline documents that include scope, assumptions, schedules, and cost estimates.

These data sources should be used to answer as many of the checklist questions as possible. Project team members should be encouraged to use their expertise to supplement the existing information. At this point in the data collection process, it must be kept in mind that there is one more data collection activity available to the project team, that of conducting a walk-around assessment of the assets. Thus, answering some questions may be deferred until after the walk-around.

Step 4. Conduct Walk-Around Assessment of Assets

The purpose of this step is to collect data about assets that can only be accomplished through an on-site, 'hands-on' assessment. This step in the process needs to focus on collecting data that were not found to exist in current documentation and/or were of poor quality in the current documentation and to verify data found in project documentation. Easy-to-use-in-the-field building status and asset status sheets have been prepared and field tested (see Figure 4). Time and effort to complete these data acquisition sheets will be kept to as low as possible while still yielding sufficient data for the LCA.

The project team needs to carefully consider who should walk-through the buildings to do the assessments. It is recommended that a walk-through team be assembled and have the following composition: facility manager/engineer; building maintenance engineer; surveillance and maintenance project manager; decontamination and decommissioning project manager; industrial realtor; metals recycler; and used equipment broker. The walk-through team members need not be the same as the project team members. Walk-through team members who are not project team members will require a thorough pre-walk-through briefing to ensure that they understand the task at hand and their expected contributions.

Decision Alternatives Assessment

This component of the LCAS focuses on identifying decision alternatives, specifying decision evaluation criteria, and assessing alternatives over the criteria. This component uses the data collected, as described above. Of course, the development of the questions in the sheets discussed above was guided by strong *a priori* beliefs as to the general nature of the decision alternatives and evaluation criteria. However, there can be numerous variations of each basic decision alternative that the collected data should be able to support the assessment of. In addition, if through the course of iterating over newly devised decision alternatives it is determined that additional decision criteria need be specified, then it is expected that the expertise of the project team will be sufficient to augment the collected data to assess the alternatives over the new decision criteria.

The data collection component was designed to foster consideration of the following three general classes of disposition alternatives:

- disposal — move materials, which includes everything in the buildings and all materials that compose the buildings, to appropriate mixed/hazardous/solid waste disposal units;
- recycle — materials, including materials that compose the buildings (e.g., steel and concrete) and capital equipment (e.g., stainless steel, copper), are sold for scrap;
- reuse – capital equipment (e.g. pump, motor, drum) is re-used for its original purpose. Buildings are used by private sector companies.

The data collection component was designed to allow assessment of decision alternatives over these six evaluation criteria:

- life cycle cost — calculate net present value of all monetary costs and benefits associated with an alternative (this includes all costs to the government regardless of which organization bears those costs);
- environmental impacts — construct a scale based on impacts on air quality, water quality, land use, solid waste, plant and animal species, etc.;

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- ▸ public and worker health and safety impacts — estimate expected fatalities in population from both radiological and non-radiological causes (e.g., chemical exposure, transportation accidents, industrial accidents);
- ▸ pollution prevention — estimate volume of material disposed, by type of material;
- ▸ programmatic impacts — judge technical risk, ability to meet milestones, time to implement, replicability, and regulatory impacts; and
- ▸ reindustrialization impacts — estimate impact on local economy measured in Gross Local Product, employment; bringing in non-government tenants; private-sector participation.

For the prototype, much of the information collected on the three sheets will be entered into a database system. Initially, effort will focus on inputting cost information into a spreadsheet program that will calculate life cycle costs and volumes of materials that could be disposed of for each alternative. Over time, the database element of the LCAS will be enhanced. The sophistication of the database component will depend upon the expected scale of implementation of this methodology and the number of users of the database system. For this prototype, this component was built using a common PC spreadsheet product. A next step in sophistication would be to use a more sophisticated database software package. In addition, future versions of this system could be built around a laptop or even palmtop implementation, where forms for the data acquisition sheets would be developed in the database language so that users could enter the data directly into the computer forms while in the field and have the data automatically entered in the database component.

An important task in the decision alternative assessment process involves developing material flow diagrams for each decision alternative. Examples relating to a decision problem in Oak Ridge pertaining to recycling or disposing of metals from the East Tennessee Technology Park are contained in Figures 1 and 2, respectively. The flow diagrams make explicit all activities involved with recycling and disposing materials. Once the project team is satisfied that it understands the logistics involved with a decision alternative, then it can be confident that all costs, environmental impacts, health and safety impacts, and programmatic impacts have been identified. Also, the project team can be confident that the spreadsheet model has all relevant inputs.

Assessments of the decision alternatives over the six evaluation criteria will be made in the following way in the prototype LCAS:

- ▸ life cycle cost — the spreadsheet model will output net present value estimates for each alternative;
- ▸ environmental impacts — experts on the project team will make qualitative judgements (e.g., very high to very low) based upon relevant evidence collected on the sheets, applicable databases and software, and literature review;
- ▸ public and worker health and safety impacts — experts on the project team will make qualitative judgements (e.g., very high to very low) based upon relevant evidence collected on the sheets, applicable software such as RESRAD, and literature review (note: because of the requirement that all applicable federal, state, and local laws will be met, it is not expected that the alternatives will vary much over this criterion and certainly no alternatives will be unsafe);
- ▸ pollution prevention — the spreadsheet model will output volumes and types of materials disposed of and then experts on the project team will make subjective qualitative judgements (e.g., very high to very low) based upon relevant evidence collected on the sheets;
- ▸ programmatic impacts — as part of the data collection effort, every effort will be made by the project and walk-through teams to elicit from DOE-site decision makers what they feel might be the programmatic impacts of each decision alternative and then these qualitative reports will be translated into a very high to very low scale; and
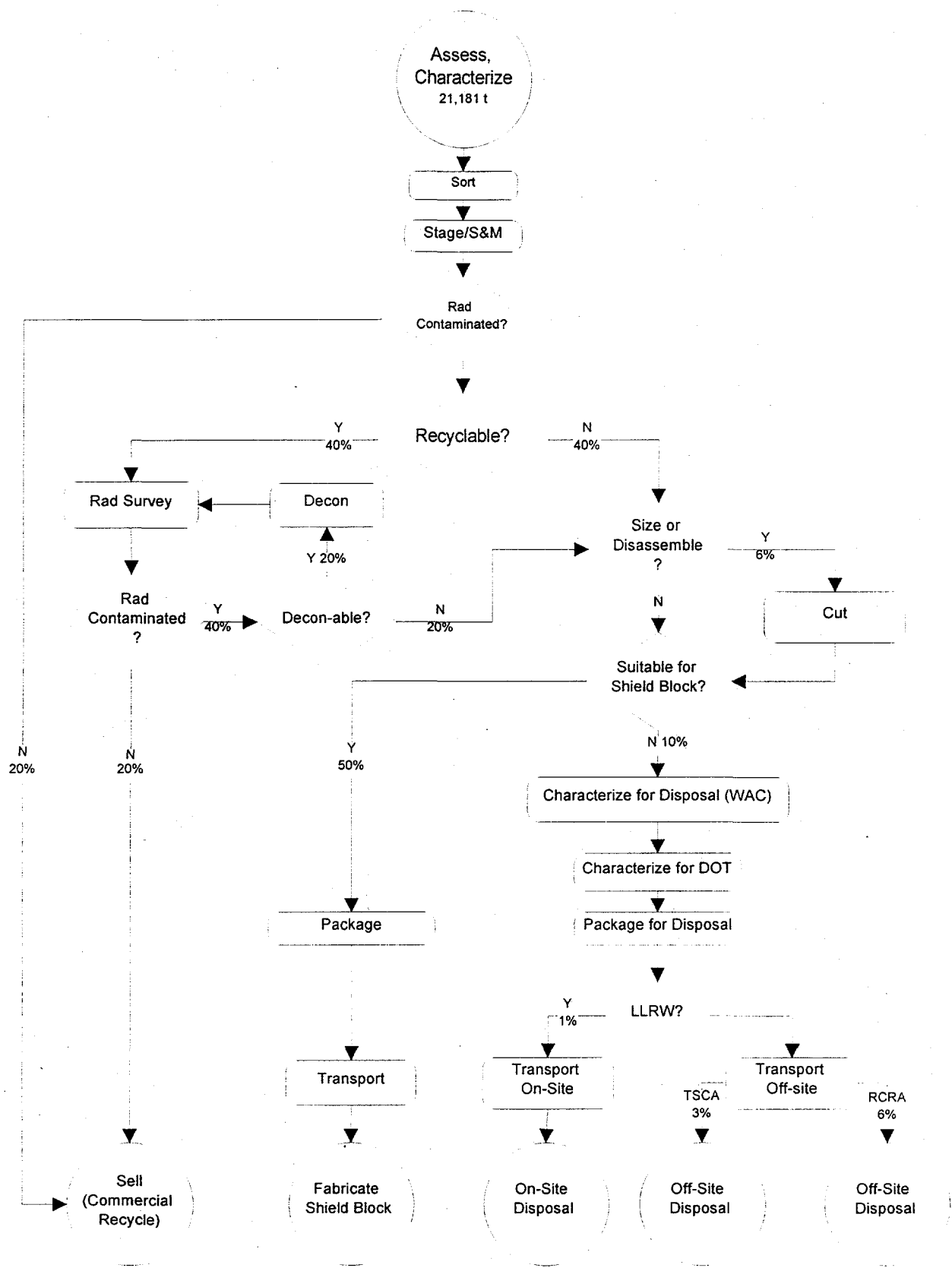
Figure 1. Materials Flow Diagram: Sell Uncontaminated Metals Alternative

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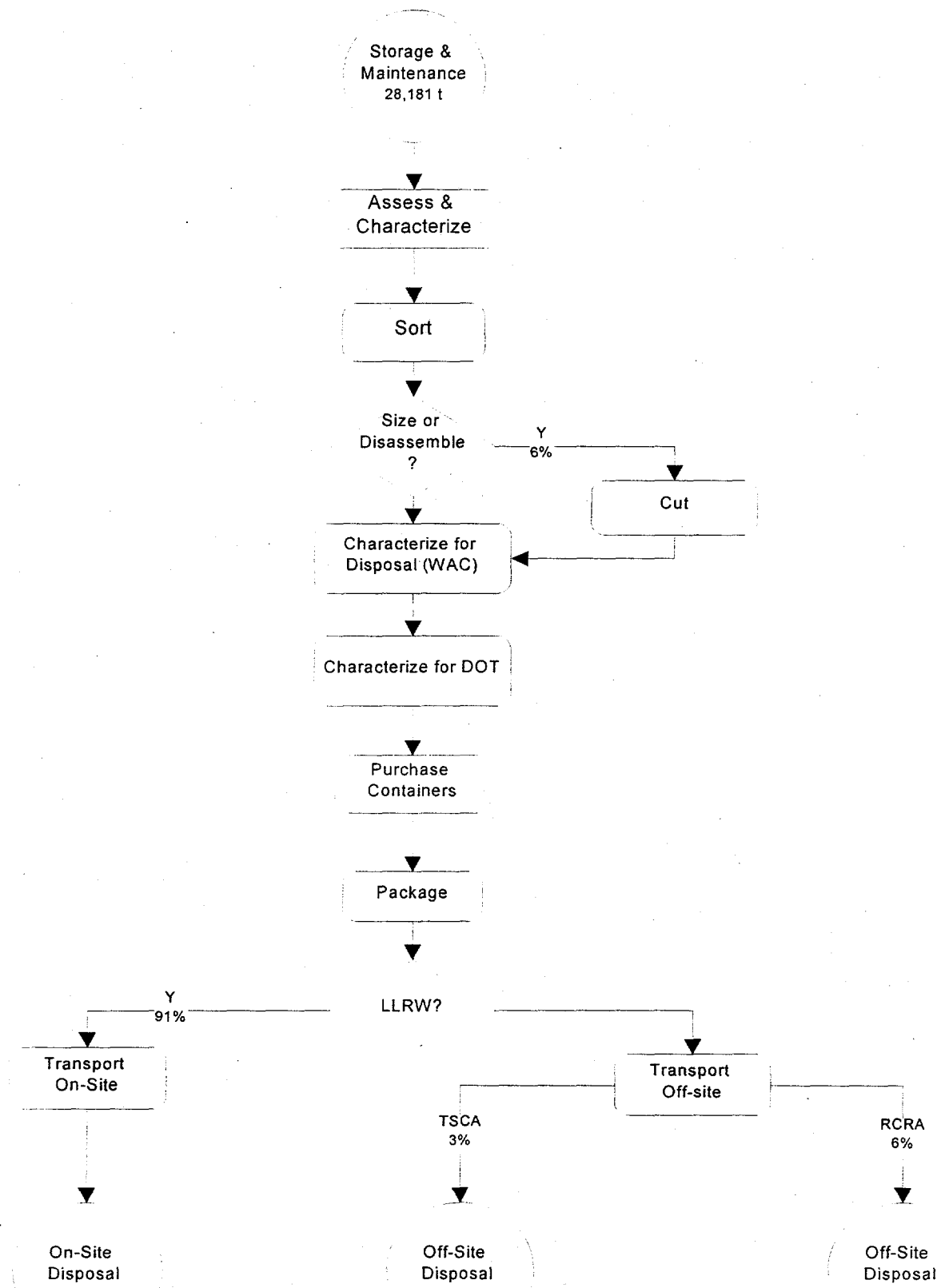
Figure 2. Materials Flow Diagram: All Materials to Disposal

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▸ reindustrialization impacts — as part of the data collection effort, every effort will be made by the project and walk-through teams to elicit from decision-makers what they feel might be the reindustrialization impacts, particularly the number of jobs created, for each decision alternative.

As appropriate, sensitivity and uncertainty analyses, and value of information analysis should be performed to augment the above approach. An extremely sophisticated LCAS could automate all assessments of decision alternatives over evaluation criteria. Using expert system technology, data could be drawn from the database to identify situations where impacts of any sort could be very high or high or medium or low or very low. These types of systems are costly and time consuming to develop, however. A large number of users over a long number of years would be needed to justify this effort. In addition, the more that computers are programmed to render these types of judgements, the less flexible becomes the entire LCAS. This is because the system may not be programmed to cover all possible decision criteria or to interpret criteria in all possible manners. On the positive side, increased automation can help to standardize unused asset decision making across buildings and capital equipment assets, across decision makers at a site, and across DOE sites.

Making the Decisions

The results of this component of the LCAS are decisions regarding the disposition of the buildings and capital equipment assets under consideration. In many situations, such as that depicted in Figure 3, the decision is clear. The third alternative, reuse equipment and sell scrap, is at least as good as the alternatives for every attribute and strictly better for at least one attribute. This alternative is said to "dominate" the others, and is the clear winner. Arriving at reasonable and defensible decisions, however, may be quite challenging in situations where no decision alternatives are dominant, no decision alternatives appear reasonable, and multiple stakeholders need their say in the decision rendering process. The following paragraphs address each of these issues.

No Decision Alternatives Dominate

In this situation, it appears that no decisions dominate. In other words, no one decision alternative appears to score best over all decision criteria. Whether this is the case or not, it is always recommended to generate visualizations of the decision information to represent how well each alternative meets each criterion. Figure 3 presents such a display. The figure has three rows, which represent three alternatives being considered: dispose of all material; sell all material as scrap; and reuse equipment, sell remaining material as scrap. The columns represent the before mentioned six evaluation criteria. The cells of the matrix contain scores for each alternative for each criterion. Life cycle costs are scored in dollars; the remaining five are scored according to a five point best-to-worst scale. These latter scores are represented by visualizations that can quickly and intuitively communicate the results.

The visualization, then, sets the basis for the decision. Three general approaches or heuristics can be used to support a decision at this point. First, it may be possible to simply mount a logical argument in support of one of the decision alternatives. The visualization may indicate that one alternative scores best on five of the six criteria and everyone knows that the sixth criterion is not very important. In this situation, one of the alternatives can easily be supported.

Second, it may be possible to eliminate alternatives that do not meet minimum criteria thresholds. In this process, known as elimination-by-aspects, alternatives that cost too much may be eliminated from further consideration, as could be alternatives that may suffer from legal complications, and take way too long to

implement and complete. After eliminating one or more alternatives, it could be that it is now straightforward to argue which of the remaining alternatives is best.

Third, in situations where it is difficult to argue which alternative is best, it is recommended that weights be assigned to each evaluation criterion (where, by convention, the weights add to 1.0). All scores in the decision matrix need to be converted to a standard scale (e.g., 1-5) where more is better. Then for each alternative, each criterion weight is multiplied by the score of that alternative over that criterion, and all the resulting weighted scores (in this case six) are summed together to yield an overall score for that alternative. Assuming a cell score of 5 is good and 1 is bad, then in this example, which refers to Figure 3, the maximum score an alternative could receive is 5 and the minimum score is 1. One could argue, then, that the alternative with the highest score be chosen.

Life Cycle Analysis
Hypothetical Disposition of Building XXX

Disposition Alternatives	Life Cycle Cost	Environmental Impacts	Public and Worker Health and Safety Impacts	Pollution Prevention	Programmatic Impacts	Reindustrialization Impacts
Dispose of all material (baseline)	$1 M	◯	◒	⬤	◯	◯
Sell all material as scrap	$0.8 M	◓	◒	◒	◓	◓
Reuse equipment, sell remainder as scrap	$0.7 M	◒	◒	◒	◓	◒

Best ◄————————► Worst

Figure 3. Example Life Cycle Analysis: Hypothetical Disposition of Building XXX

No Decision Alternatives Appear Reasonable

One difficulty with this outcome, and with decision making in general, is that it is possible that none of the decision alternatives receive reasonable scores. None may meet pre-specified criterion thresholds or pass more intuitive judgements. In these situations, the only recourse is to revisit the decision alternatives and develop new ones. Based on past experience, the optimum alternative may well prove to be a phased, hybrid approach of the ones currently being assessed. It may be that this iteration may then require additional data collection. Of course, the decision alternative assessment step will have to be conducted for all new alternatives. Iteration would continue until an acceptable alternative is discovered.

Another difficulty with this outcome is that different people may hold the evaluation criteria in different levels of regard. In other words, different people may use different weights, and, therefore, may end up with different preferences for alternatives. By itself, this is not a problem as people with different interests, backgrounds, and value systems would be expected to have different values. In fact, much political discourse surrounds people's 'values.' A strength of the LCA approach is that in public discussions of the decision under consideration, the visualization in Figure 3 can be augmented to show the weights assigned to each criterion by different stakeholders. Then everyone in the room will be able to understand as explicitly as our language and communication skills allow where everyone one else in the room stands with respect to values and preferred decision outcomes. Discussions could ensue to craft a consensus on an alternative. New alternatives could be explored that could bridge the gaps among stakeholders.

Problems arise in situations where the public needs to be involved in the decision making process and are not involved 'early and often.' Simply put, the public cannot be brought into the LCA process at the back end, provided a visualization such as shown in Figure 3, and asked for their opinions. On principle alone, the stakeholders will be motivated to be argumentative, resistive, and disruptive. Successful public participation efforts bring stakeholders into the process in the beginning.[4] In the decision context being explored in this paper, early involvement with the public may focus on specifying evaluation criteria, and identifying any assets (particularly buildings) that should receive priority attention.

Judgement is needed at the beginning of the process to determine the appropriate extent of public involvement in the decision making process. For decisions of small consequence that are not controversial, decisions could be based simply upon recommendations of analysts. For decisions of more consequence that need cooperation from community leaders, maybe an 'elite corps' decision process is warranted. For decisions that have ramifications for the entire community, more time and effort to involve the broadest spectrum of stakeholders is desirable.[5]

DEPLOYMENT EXPERIENCES

At the time of this writing, the data collection component of the LCAS has been tested in the field involving a building and associated equipment on the Oak Ridge Reservation. The building was visited by a walk-through team and other data sources were consulted. The resulting building status sheet is found in Figure 4.

Several useful insights came from this test. First, there may be cases where the walk-through team needs to don protective clothing. Bulky gloves in particular may make filling out the sheets very difficult. In these situations, it is recommended that the walk-through team use a tape recorder to capture their observations and answers to checklist questions. Using a tape recorder for all walk-throughs is not a bad idea in any case. In addition, bringing a camera to record images of assets or issues associated with the building is also useful. Tying images to tape recorded observations is particularly important.

A second useful observation is that walk-throughs take time and logistical organization. To minimize time and logistical problems, it is recommended that existing data sources be mined as thoroughly as possible prior to walk-throughs. A third insight is that in situations where assets could potentially be reused, people need to be part of the reuse team who can imagine what those uses could be.

Building XXX

Location:	E.T.T.P. 8 mi. W of Oak Ridge, TN
Age:	Approx. 45 yrs.
Dimensions:	520' X 160'
Sq. Ft.	94,800 ft^2; 30,000 ft^2 highly contaminated (limited use after decon)
Construction:	Structural Steel w/masonry & transite siding
Floor:	Concrete
Basement:	25' wide tunnel complex for piping, elevator shafts, pump stations, and groundwater sumps.
Roof:	Steel decking w/gravel & asphalt on fiberglass
Areas:	Office, Mfg., Storage
Utilities:	Gas, water, steam heat, sewer, electric
Condition:	Good
Fire Protection:	Interior: Sprinkler system. Exterior: 6 hydrants
Restrooms:	3 w/showers
Service:	Rail siding 200' S; Asphalt yard; Blair Road entrance; 8' security fence; 7 roll-up doors

Office Area

Size:	180' x 60'
Sq. Ft.	10,800 ft^2
Offices:	7
Conference Rooms:	1
Laboratory:	1 16' x 20'
Restrooms:	3
Showers:	3
Lunchroom:	1
Env. Controls:	Wall type heating & air conditioning units
Computer Wiring:	Yes
Telephone Wiring:	Yes
Code Status:	Yes
Status:	Occupied

Mfg. Area

Size:	100' x 540'
Sq. Ft.	54,000 ft^2
Overhead Clearance:	40' x 540' @ 25'; 60' x 540' @ 46'
Lighting:	Excellent
Ventilation:	10 Roof Fans
Env. Controls	No
Access:	7 roll-up doors
Bridge Cranes:	Six 2 to 40 ton; uncertified
Access Requirements:	Yes
Code Status:	Electrical - No
Contaminated Condition:	Radiation, metals, haz waste, asbestos contaminated
Status:	Equipment removal & de-coning building

Figure 4. Example Building Status Sheet: Building XXX, Oak Ridge Reservation (Note: Building XXX was built in 1954 to provide radiological decontamination and uranium recovery activities. Also contained a cylinder cleaning shop, nickel plating shop, and compressor and valve rebuilding shop. The building was shut down in 1988. Currently undergoing decontamination and cleanup for reuse.)

CONCLUDING COMMENTS

This paper describes an LCAS developed to assist DOE decision makers with D&D, P2, and asset recovery. The LCAS is built upon well-tested decision analysis methods. The LCAS process is designed to meet the needs of the DOE sites, which includes the need for meaningful stakeholder participation. It must be noted that this approach is not biased toward any class of decision outcomes. As long as the set of decision alternatives being considered is comprehensive, all reasonable strategies will be explored and the strongest alternatives will be weighed against each other. This is the fundamental tenet of sound decision analysis.

The LCAS has been successfully applied at Oak Ridge and Ohio Operations Office sites and has been proven to be a robust decision-making aid in a variety of decision contexts. In the coming months, it will be deployed at the Hanford Reservation and at other DOE sites. This paper presents the example of disposition of facilities and capital assets. However, it must be noted that this approach can be applied to decision contexts beyond facilities and equipment. This approach, with appropriate changes in the data collection sheets, can be applied to the wide variety of pollution prevention and mortgage reduction applications that exist in the DOE complex.

ENDNOTES

1. See Yuracko, K.L. et al., "A Life Cycle Analysis Approach to D&D Decision-Making," Proceedings of Spectrum '98, Denver, CO, September 1998. Yuracko, K.L. et al., "A Life Cycle Decision Methodology for Recycle of Radioactive Scrap Metal," *Int. J. LCA*, 2(4), 223-228 (1997). Yuracko, K.L. et al., "Fernald's Dilemma: Recycle the Radioactively Contaminated Scrap Metal, or Bury It?" *Resources, Conservation, and Recycling*, 19, 187-198 (1997). "Preliminary Life Cycle Analysis for a Recycling Program for Metals from Building K-31 at the Oak Ridge K-25 Site," ORNL/ER-346, Oak Ridge National Laboratory, Oak Ridge, TN (1995).
2. Two seminal texts in this field are: Keeney, R. and Raiffa, H. 1976. *Decisons with Multiple Objectives: Preferences and Value Tradeoffs*. New York, Wiley; and von Winterfeldt, D. and Edwards, W. 1986. *Decision Analysis and Behavioral Research*. Cambridge: Cambridge University Press.
3. See Keeney, R. 1992. *Value-focused Thinking: A Path to Creative Decision Making*. Cambridge, MA: Harvard University Press.
4. Peelle, E., Schweitzer, M., Munro, J., Carnes, S., and Wolfe, A. 1996. "Factors Favorable to Public Participation Success," *Proceedings of the National Association of Environmental Professionals*, Houston, Texas, June 2-5, 601-610.
5. See Tonn, B., English, M., and Travis, C. 1999. "Frameworks for Understanding and Improving Environmental Decision Making," *Journal of Environmental Planning and Management*, (forthcoming).