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OPTIMAL FACILITY AND EQUIPMENT SPECIFICATION TO SUPPORT COST-EFFECTIVE RECYCLING

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ABSTRACT

We demonstrate a project management approach for D&D projects to select those facility areas or equipment systems on which to concentrate resources so that project materials disposition costs are minimized, safety requirements are always met, recycle and reuse goals are achieved, and programmatic or stakeholder concerns are met. We examine a facility that contains realistic areas and equipment, and we apply our approach to illustrate the different results that can be obtained depending on the strength or weakness of safety risk requirements, goals for recycle and reuse of materials, and programmatic or stakeholder concerns.

I. INTRODUCTION

The purpose of this paper is to present a management approach that may be used to select facility areas or equipment areas on which to allocate resources so that D&D project life cycle costs are minimized while simultaneously meeting goals in areas of safety, recycle and reuse, and programmatic or stakeholder acceptance. For purposes of this paper, emphasis is placed on the endpoint of material recycling.

The approach has a broad range of application to facility deactivation to include work scope planning and endpoint or disposition tradeoff analyses. This approach for selecting a portfolio of D&D projects should be performed in conjunction with the Life Cycle Analysis D&D approach described in Yuracko (1998), a method for determining the amount of material to be recycled, reused, and disposed, in any given D&D project.

II. APPROACH

All deactivation projects must be completed on schedule, within budget, and safely. The U.S. Department of Energy (DOE) has produced *The Facilities Deactivation Guide, Methods and Practices Handbook* to assist project management in using end points as a means to translate broad mission statements to explicit goals that are readily understood by engineers and craft personnel who do the work. DOE requires that a deactivated facility satisfy specific requirements in the areas of completion, meeting regulatory requirements, maintaining physical integrity and material stability, ensuring security requirements are met, and providing and implementing a Surveillance and Maintenance Plan. The end point of interest discussed in this paper is recycling or reuse of material from a surplus facility.

From a recycling perspective, then, the question is "what equipment and material can be cost-effectively removed and sent to market?" Since a large volume and amount of surplus facilities and equipment/material can be recycled without extensive decontamination, it seems prudent to direct early recycling efforts to an identification of such elements and allocate a reasonable amount of resources to accomplish the recycling or reuse.

Our approach to answer the question is as follows:

- Define an operational end point, or set of end points, that must be achieved. For endpoint EP_1, let $EP_{1(now)}$ denote all key facilities, equipment, and systems that are planned to be deactivated now and dispositioned (recycled and/or disposed), and denote as $F_1, \ldots, F_n$ each of those

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facilities, equipment, and systems in $EP_{1(now)}$. Let $EP_{1(Later)}$ denote the systems for which no deactivation will occur in the immediate future, and denote as $G_1, \ldots G_m$ the facilities, equipment, and systems in $EP_{1(Later)}$. Observe that these facilities, etc. will be placed under a surveillance and maintenance program.

- Quantitatively determine the worker safety risk (S_i), the potential for recycling (R_i), the programmatic or stakeholder concern (K_i), and the cost (C_i) associated with removal, treatment, and disposition (recycle and/or disposal) of the facilities or equipment associated with facility or equipment system F_i for the endpoint EP_1. Note that cost is a function of the percentage of material to be recycled. Note also that while we have considered safety to be worker safety only, it could easily include public safety and thus be considered a composite safety risk measure.

- Specify quantitative target levels for safety (TS_{EP1}), potential for recycling (TR_{EP1}), and programmatic or stakeholder concerns (TK_{EP1}) that must be met for endpoint EP_1.

- Specify which facilities or equipment must be immediately deactivated, decontaminated, and disposed or recycled. For example, suppose we are examining ten systems. Facility or equipment systems F_1, F_5, and F_7 must be deactivated, decontaminated, and disposed or recycled because of regulatory or contractual requirements. The remaining facilities or equipment systems (F_2, F_3, etc.) are choice variables to either be dispositioned now or included as systems to be dispositioned later.

- Determine the subset, S_{EP1}, of the facilities or equipment that minimizes the total cost and meets the safety, potential for recycling, and programmatic or stakeholder concerns specifications, including the constraint that some facilities or equipment must be immediately deactivated, decontaminated, and disposed or recycled. For example, S_{EP1} could be composed of F_1, F_2, F_5, F_6, F_7, and F_{10}.

- Define a new endpoint, EP_2, and perform the above steps. Select the endpoint from all endpoints that minimizes total cost. The list of facilities or equipment represents the least cost set of facilities or equipment systems to be deactivated, decontaminated, and disposed or recycled. The facilities or equipment systems not chosen represent those that fall under a surveillance and maintenance program.

The technique for accomplishing the above approach is grounded in quantitative production management theory, and it relies on the technique of mathematical programming. The technique has been successfully demonstrated for optimal project selection in Redus (1997, 1996), Redus and State (1997), and Redus and Sharp (1996). Mathematical programs allow for the investigation of multiple endpoints and their associated combinations of facilities and equipment types while simultaneously examining the effects of such specifications as safety, potential for recycling, and programmatic or stakeholder concerns.

Expressed as a mathematical program, we want to choose those F_i for any EP_k to minimize $\Sigma_i C_i F_i$ and ensure that the following constraints are met:

$\Sigma_i S_i \leq TS_{EPk}$
$1 - \Pi_i(1-R_i) \geq TR_{EPk}$
All $K_i \geq TK_{EPk}$
Required F_i are performed
$F_i = 0$ or 1

A subset of facilities or equipment types is selected from the set of all possible facilities or equipment types so that total costs are minimized while meeting specific safety, potential for recycling, and programmatic or stakeholder concerns constraints. Changing the constraint requirements offers insight into the cost efficiency of various end points and the marginal values of specific facilities or areas that are to be disposed or recycled.

III. RESULTS

The objective is to determine which facilities or equipment should be deactivated, decontaminated, and disposed or recycled in order to minimize total cost while meeting safety, potential for recycling, and programmatic or stakeholder concerns specifications.

Using illustrative facilities and equipment for a deactivated operation, consider the following hypothetical summary data, Table 1. For example, under a proposed endpoint alternative called the "Base Case," project 1 represents the deactivation of the main control room and the disposition of the material in the control room.

- Safety risk is a population risk measure. We use the proxy measure of expected number of worker fatalities during any D&D operations associated with disposition of the material or equipment in the facility area.

- Potential for recycle is the percentage of material recycled in the open market within a specified planning horizon. For example, the potential for recycling the resources in the main control room is over 40%; namely 44% of the material can be recycled.

- Programmatic or stakeholder concern uses a 1 to 9 scale indicating the desire to recycle the resources. Low values indicate little programmatic or stakeholder desire to recycle the resources and high values indicates a strong programmatic or stakeholder desire. For example, the program or the stakeholders have moderate interest (Value = 3) in seeing the material in the main control room recycled.

- Cost represents the life cycle cost ($K) to accomplish deactivation, decontamination, and disposition. For example, the life cycle cost to deactivate, decontaminate and disposition the material in the main control room is $132K. Cost is estimated as a function of the safety risk and the percentage of material recycled using multiple regression or some suitable means.

Table 1. Raw Data Used for Study

ID	Facility Area or Equipment	Safety Risk (n)	Potential for Recycle (%)	Programmatic or stakeholder Concern (Stanine)	Cost ($K)
1	Main Control Room	6.45E-05	0.44	3	132
2	Instrument Gallery	4.41E-05	0.10	3	547
3	Hot Shop	7.20E-05	0.15	9	764
4	Meteorology Instrument Shed	7.08E-05	0.32	3	579
5	Sump Level Detection	4.31E-06	0.17	3	725
6	Sump Pumping	9.44E-05	0.22	5	496
7	HVAC Main Exhaust	6.37E-05	0.44	3	773
8	HVAC Exhaust HEPA	5.11E-05	0.01	5	614
9	External Demineralizer Bldg.	5.99E-06	0.24	3	214
10	Elevator #7	3.48E-05	0.18	3	537
11	Condensate Storage Tank	7.73E-05	0.25	7	690
12	Lab Hoods	5.22E-05	0.42	9	894
13	N Cell Glove Boxes	4.49E-05	0.08	9	643
14	Diesel Generators	5.90E-05	0.12	9	123
15	HVAC Supply	8.33E-05	0.35	3	865
16	Local HVAC #1	9.47E-05	0.40	3	707

We defined a base case and five other end point cases to determine the facilities and equipment systems to be disposed and recycled at the least cost:

- The Base Case consisted of maintaining an overall safety risk of less than 1E-03, ensuring that a composite recycling potential of 0.75 was met, meeting a moderately important level of programmatic or stakeholder concern (a numerical value of 3), and choosing at least 8 facility areas or equipment systems to recycle.

- The 10x Safety case represents a tightening of safety risk by an order of magnitude, namely changing the allowable safety risk from 1E-03 to 1E-04. There are no constraints on selection of a minimum number of facility areas or equipment systems.

- The -25% Recycle case represents relaxing the recycling opportunity from 75% to around 55%. Safety risk cannot exceed 1E-03. There are no constraints on selection of a minimum number of facility areas or equipment systems.

- The +25% Recycle case represents tightening the recycling opportunity from 75% to around 90%. Safety risk cannot exceed 1E-03. There are no constraints on selection of a minimum number of facility areas or equipment systems.

- The <u>Base Case and Include 12 and 13 case</u> represents the explicit inclusion of recycling Items 12 and 13, Lab Hoods and Glove Boxes, respectively, under the Base Case. There are no constraints on selection of a minimum number of facility areas or equipment systems.

- The <u>7.5x Safety and +25% Recycle case</u> represents tightening the safety and the recycling constraints respectively. There are no constraints on selection of a minimum number of facility areas or equipment systems.

The optimal selection of facilities and equipment are presented in Table 2 and cost parameter values are illustrated in Figure 1.

These are the recommended facilities and equipment that should be deactivated, decontaminated, and dispositioned in order to *minimize total cost while meeting safety, potential for* recycling, and programmatic or stakeholder concerns specifications.

The least cost end point to choose is either the 10x Safety or the -25% Recycle case with an expected cost of $2,628K. All other facilities or equipment systems should be placed into the S&M program.

Of key interest is the fact that tightening recycling constraints (the +25% Recycle case and the 7.5x Safety and +25% Recycle case) requires us to choose more facilities or equipment at approximately the same percentage increase over the Base Case.

Tightening safety requirements (10x Safety) and relaxing recycle requirements (- 25% Recycle) results in a lower cost at the expense of reducing the number selected for recycling from 8 to 7.

Finally, including the lab hoods and the N Cell glove boxes as required equipment to be recycled only slightly increases the cost from the Base Case at the expense of eliminating the material in the Meteorology Instrument Shed and the HVAC Exhaust HEPA.

Table 2. Results of Optimal Facility and Equipment Specification

	Minimum Cost ($K)	3,242	2,628	2,628	5,282	3,586	5,282
	Number Selected to Recycle	8	7	8	11	8	11
ID	Facility Area or Equipment	Base Case	10x Safety	-25% Recycle	+25% Recycle	Base Case and Include 12 and 13	7.5x Safety and +25% Recycle
1	Main Control Room	■	■	■	■	■	■
2	Instrument Gallery	■	■	■	■	■	■
3	Hot Shop						
4	Meteorology Instrument Shed	■	■	■	■		■
5	Sump Level Detection						
6	Sump Pumping	■	■	■	■	■	■
7	HVAC Main Exhaust						
8	HVAC Exhaust HEPA	■			■		■
9	External Demineralizer Bldg.	■	■	■	■	■	■
10	Elevator #7	■	■	■	■	■	■
11	Condensate Storage Tank				■		■
12	Lab Hoods					■	
13	N Cell Glove Boxes				■	■	■
14	Diesel Generators	■	■	■	■	■	■
15	HVAC Supply						
16	Local HVAC #1			■	■		■

■ Indicates "select these components of the facility area or the equipment systems to recycle"

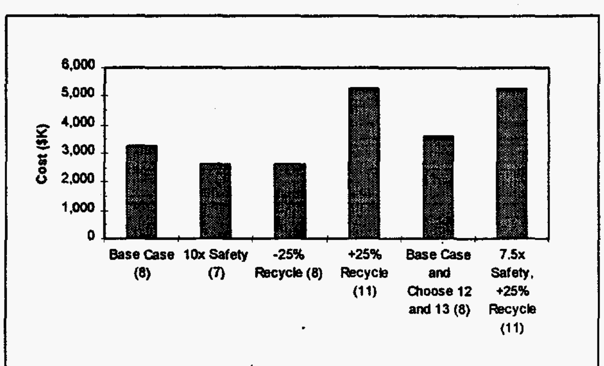
IV. CONCLUSION AND DISCUSSION

We have demonstrated a project management approach to select those facility areas or equipment areas on which to concentrate resources so that project costs are minimized, safety requirements are always met, goals for recycle and reuse of material are achieved, and programmatic or stakeholder concerns are met. We have examined a facility that contains realistic areas and equipment, and we have employed our approach to illustrate the different results that can be obtained depending on the strength or weakness of safety requirements, demands for recycle and reuse of materials, and programmatic or stakeholder concerns.

There are two current limitations in our methodology. First, we have not specifically addressed how to balance the allocation of facilities and equipment systems between disposition and S&M programs. We suggest including cost estimates of S&M in the optimization. Second, we have treated safety risk as worker safety only. Refining this parameter to include public health risk should be accomplished. While not demonstrated in our example, a premium representing willingness to pay for more recycling can also be included in specific evaluations.

As a management-planning tool, our approach should be incorporated into project planning and scheduling to meet national recycle needs in a cost-effective manner. End points can be compared, and sensitivities and trade-offs can be analyzed between project costs, required safety thresholds, recycling goals, and programmatic or stakeholder concerns. Finally, there is always a question of uncertainty associated with the estimates for the cost, safety, recycle potential, and programmatic or stakeholder concern parameters. This can be addressed by examining an endpoint with various values (e.g., worst case, nominal value, and optimistic case) of these parameters.

Figure 1. Costs for Selected End Point Cases



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