Decision Support Tool for Prioritization of Surveillance and Maintenance Investment – 9342

L.Y. Velez
Applied Research Center, Florida International University
10555 West Flagler Street, Suite 2100, Miami, FL 33174

T.B. Conley
Oak Ridge National Laboratory
P.O. Box 2008 MS6197, Oak Ridge, TN 37831

ABSTRACT

The Department of Energy (DOE) currently faces a difficult task in the disposition of the numerous excess or to-be excessed facilities owned by the Department. Many of these facilities are in various physical conditions and contain potentially hazardous nuclear, chemical, radiological or industrial materials left behind as a byproduct of nuclear weapons production, nuclear powered naval vessels and commercial nuclear energy production [1]. During the last period of a facility's life cycle, it is important that surveillance and maintenance (S&M) be adequate to maintain the facility within an appropriate safety envelope. Inadequate investment in maintenance can cause facilities to deteriorate to the point they are unsafe for human entry. Too often this can mean tremendous increases to cost during deactivation and decommissioning (D&D). However, experiences often show that once buildings have been declared excess and enter the transition phase (as defined in DOE G 430.1-5 *Transition Implementation Guide*), maintenance budgets are drastically reduced. This is justified by the desire to not spend money "on a building that is being torn down." The objective of this study was to provide the U.S. Department of Energy (DOE) Environmental Management (EM) federal project directors and their contractors with a decision support tool to aid in prioritizing S&M investment across a site's excess facilities so that the limited budget available can be used most effectively. The analytical hierarchy process (AHP), a multi-criteria decision making method developed by Dr. Thomas Saaty in the 1970's, was used to derive the weight of importance of a defined list of risk-based criteria and typical S&M activities. A total of 10 facilities at the Oak Ridge National Laboratory (ORNL) varying in perceived hazards and conditions were chosen to test the tool by evaluating them with respect to each risk criterion and combining these results with the weight of importance of the S&M they require. The final result was a rank of S&M activities to be performed on all the facilities based on the relative weight of importance of the activity coupled with the risk posed by the facility. This method addressed the needs of all of the facilities without ignoring the S&M activities of the lower risk facilities. In doing so, the site can prevent the lower-risk facilities from becoming a higher risk in the future. The result of this study was analyzed for consistency and reflected the overall technical judgment of subject matter experts, based on the facilities used in the test. This tool can be a starting point to determine how to distribute S&M budgets, to help make consistent and risk-based decisions and to provide documentation for future reference and review. In addition, the tool is flexible enough to be modified and used at other DOE sites. Several factors which include the weights assigned to each criterion, the final rank of the facilities and the S&M actions, are subject to the judgment of the decision maker. For this reason, a sensitivity analysis will be the next step to improve the decision tool.

INTRODUCTION

The Department of Energy (DOE) currently faces a difficult task in the disposition of the numerous excess or to-be excessed facilities owned by the Department. Many of these facilities are large, complex and contain potentially hazardous nuclear, chemical, radiological or industrial materials left behind as a byproduct of nuclear weapons production, nuclear powered naval vessels and commercial nuclear energy production [1]. As DOE facilities complete mission operations and are declared excess, they pass into a transition phase that ultimately prepares them for disposition. The disposition phase of a facility's life cycle usually includes deactivation, decommissioning (D&D), and surveillance and maintenance (S&M) activities. S&M activities are conducted throughout the facility life cycle, including those times when the facility is not operating and is not expected to operate again. During these last periods, it is important that S&M be adequate to maintain the facility within an appropriate safety envelope through a seamless transition to the final disposition. S&M is adjusted as transition D&D activities are completed.

Experience often shows that once buildings have been declared excess and transferred to S&M, maintenance budgets are drastically reduced and the facilities are taken "cold and dark" as quickly as possible. However, the result can be the eventual deterioration of a building to the point that it is unsafe for human entry. Thus, when D&D activities are ready to commence, risk and safety concerns posed by the unstable structure must be addressed. This can create additional cost to D&D including shoring up floors, installing netting, fall protection, and additional personal protective equipment (PPE), etc.

Structural deterioration of some Oak Ridge National Laboratory (ORNL) facilities such as 3026 C&D and the 2000 complex are proof of the long term consequences of inadequate S&M investment. The absence of maintenance, continuing roof leaks and the absence of air circulation within the buildings have contributed to their continuing deterioration. For this reason, a decision support tool for the prioritization of S&M investment was developed with the purpose of optimizing the limited funds available for S&M. This tool was tested at ORNL with a list of facilities varying in perceived hazards and conditions.

MATERIALS AND METHODS

The use of analytical techniques for risk-based prioritization has become a very useful tool in risk management. There are a number of prioritization methods available and the process of selecting the most appropriate becomes an essential part in the success of the implementation. The application of a risk-based prioritization methodology will yield a prioritized list of items by taking into consideration a known list of objectives or criteria.

This research began by analyzing a list of prioritization methods which can take into consideration a list of criteria, or objectives. These methods are known as multi-criteria decision methods (MCDM). MCDM are used to help decision makers make complex decisions; they can improve the quality of decisions by making choices more explicit, rational, and efficient [2].

The Analytical Hierarchy Process was selected from the list of MCDM because of its flexibility and its known applicability to various types of problems. AHP was developed by Dr. Thomas L. Saaty in the 1970's. This method uses a structured framework that allows for the comparison of qualitative data by means of a pair-wise comparison technique. This method mimics the way decision makers generally approach complex situations by allowing decision makers to compare two items at a time as opposed to an item to all the others simultaneously [3]. In addition, AHP is suitable for both qualitative and quantitative criteria.

The following risk criteria were identified by a group of subject matter experts at ORNL:

- Extent of contamination

    - Chemical Contamination
    - Radiological Contamination
- Facility nuclear categorization
- ES&H Concerns
    - Environment
    - Safety
    - Health
- Time until D&D
- Accumulated delayed maintenance estimates
- Time since declared excess
- Status of legacy materials cleanout

In addition to the risk criteria, a list of general S&M activities was also used in the initial tool development:

- Contamination control
- Roof repair
- Safety basis surveillance
- Ventilation
- Fire system maintenance
- Heating, ventilation, and air conditioning (HVAC)
- Steam repair
- Grounds keeping
- Structural repair
- Legacy waste removal
- Liquid waste systems

Once the criteria and the S&M activities were identified and defined, the SMEs met to do a pair-wise assessment. This assessment was done using the nine-point scale developed by Dr. Saaty [4].

Table I. Saaty's 9 Point Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two criteria are judged to be equally important.
3	Weak importance of one over another	Experience and judgment slightly favor one criterion over another.
5	Moderate importance of one over another	Experience and judgment moderately favor one criterion over another.
7	Strong importance	Experience and judgment strongly favor one criterion over another.
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between the two adjacent judgments.	When compromise is needed.
Reciprocals of above nonzero	If criterion *i* has one of the	

	nonzero numbers assigned to it when compared to activity *j*, then *j* has the reciprocal value when compared to *i*.	

Both sets of criteria were set up in a matrix format and the weight of importance of the criteria was normalized to add up to 100%.

The AHP can also be used to evaluate the alternatives with respect to each criterion. However, since this problem involves a large number of facilities and criteria, it would not be practical to do pair-wise comparison because the procedure can become long and tedious. For this reason, a new scale was developed to measure each facility with respect to each risk criterion.

Table II: Scale for the facilities evaluation

Scale Number	*Definition*
5	Very High
4	High
3	Moderate
2	Low
1	None

The subject matter experts were provided a full definition of each scale number for each criterion. Table III shows the definitions used for Facility Nuclear Categorization.

Table III: Scale definition for Facility Nuclear Categorization

Criterion	*5-Very High*	*4-High*	*3-Moderate*	*2-Low*	*1-none*
Facility Nuclear Categorization	CAT-2	CAT-3	Radiological High Risk	Radiological Low Risk	The facility is not RAD facility

Ten facilities from ORNL, varying in perceived hazards and conditions, were chosen to test the tool:

- 3026 C/D – CAT 3 facility
- 3517 – CAT 2 facility
- 2000 Complex – Radiological facility
- 2026 - Radiological facility
- 4501/4505 - Radiological facility
- 3503 - Industrial facility
- 3550 - Radiological facility
- 7710 -Radiological facility
- 2011 - Radiological facility
- 2009 - Radiological facility

The final score for each facility was calculated using the following formula:

$$FinalScore = \sum_{j=1}^{n} a_{ij} w_j \text{ , for i =1,2,3,…m} \qquad \text{(Eq. 1)}$$

Where, n = number of decision criteria, a_{ij} is the actual value of the i-th alternative in terms of the j-th criterion, and w_j is the weight of importance of the j-th criterion [4].

RESULTS AND DISCUSSION

A group of subject matter experts familiar with the ORNL facilities met to evaluate each risk criterion and S&M activity based on their expertise. The results from the pair-wise assessment are shown below as a percentage (Figure 1). The percentages were calculated by taking the weighted sum of the pair-wise assessment scores, they represent the weight of importance of each criterion with respect to each other. The extent of contamination criterion is composed of two sub-criteria, radiological and chemical. ES&H is also composed of three sub-criteria: environment, safety and health. These sub-criteria were evaluated in the same format using pair-wise comparison technique.

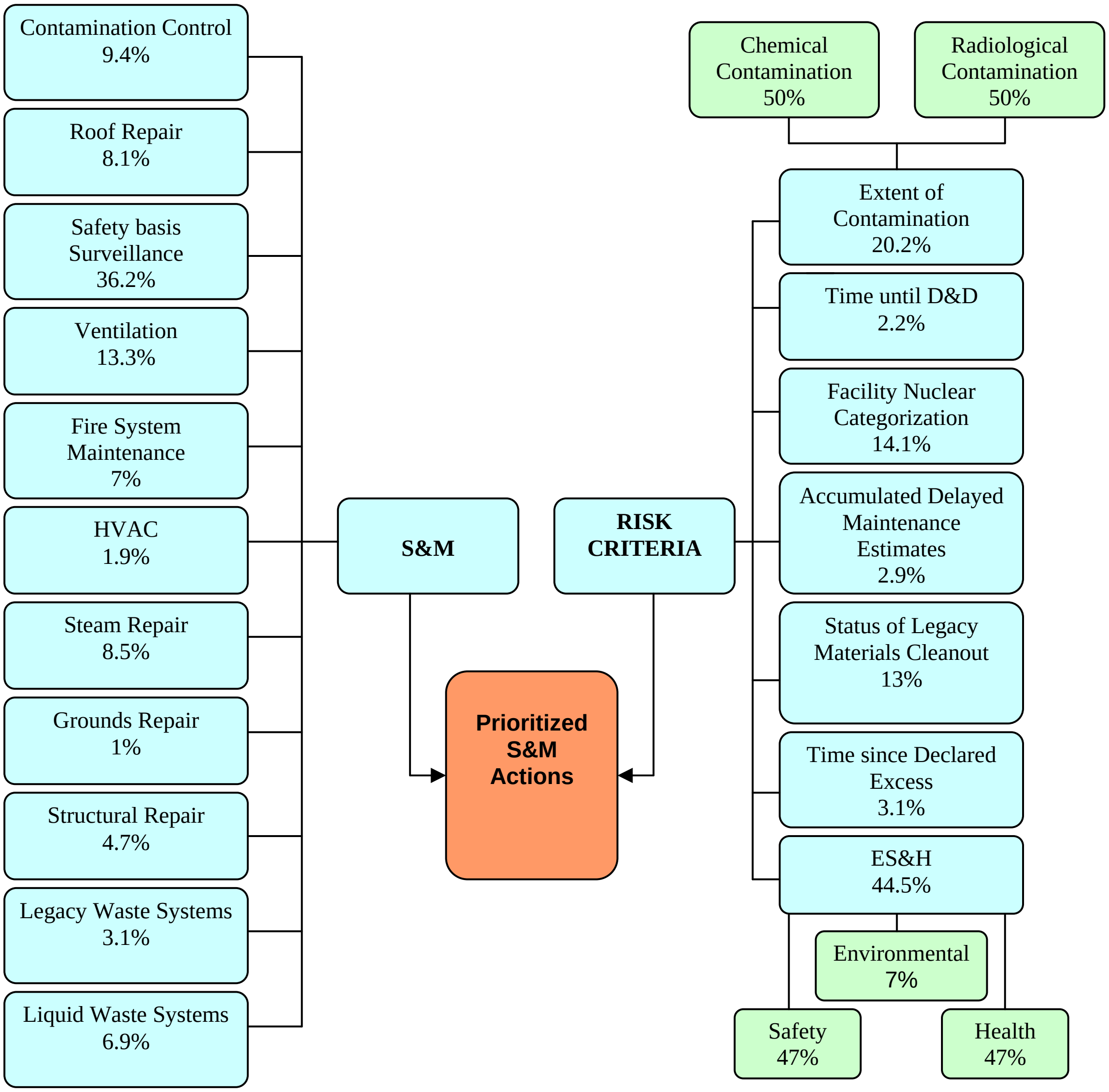

Fig. 1. Percent weight of importance based on pair- wise comparison

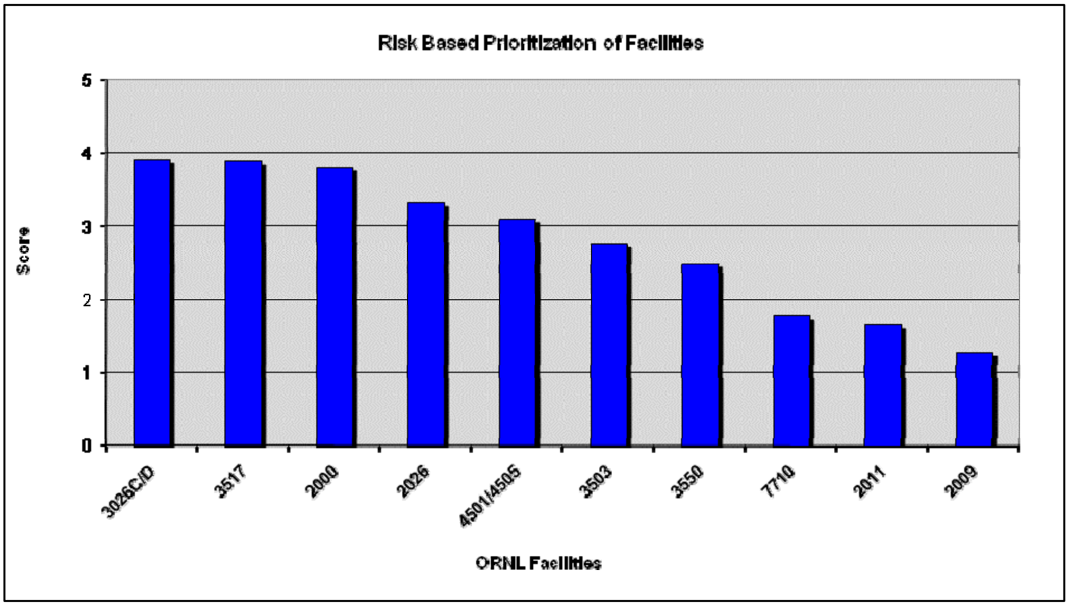

Fig. 2. Risk Based Prioritization of ORNL Facilities

Once the weight of each criterion was determined, the subject matter experts used the scale for the facilities evaluation (Table II) to evaluate each facility with respect to each risk criterion. The score assigned to the facility for each risk criterion was multiplied times the weight of importance of the criterion. The results are shown on figure 2, were the final score represents the risk of the facility. These results were combined with the weight of importance of the S&M activity they require. A table was created so that the subject matter experts could identify the S&M for each facility.

Table IV. S&M Check List

	Safety Basis Surveillance	**Ventilation**	**Contamination Control**	**Steam Repair**	**Roof Repair**	**Fire System Maintenance**	**Liquid Waste Systems**	**Structural Repair**	**Legacy Waste Removal**	**HVAC**	**Grounds Keeping**
3026C/D	x	x			x			x	x		
3517	x	x	x	x		x	x		x	x	
2000		x	x		x	x		x			x
2026	x	x	x			x	x		x	x	x
4501/4505		x	x			x			x	x	
3503			x	x	x	x			x		
3550						x		x			x
7710		x				x				x	x
2011											x
2009		x									

The final result after evaluating the facilities against each risk criterion and identifying their S&M was a rank of S&M activities to be performed on all the facilities based on the weight of importance of the activity and the risk posed by the facility (Figure 3). The score shown on figure 3 is the result of the product of the facility score times the weight of importance of the S&M. This method addressed the needs of all of the facilities without ignoring the S&M activities of the lower risk facilities. Doing so can prevent lower risk facilities from becoming a higher risk in the future. The results of this study showed consistency and reflected the overall judgment of subject matter experts, based on the facilities used in the test.

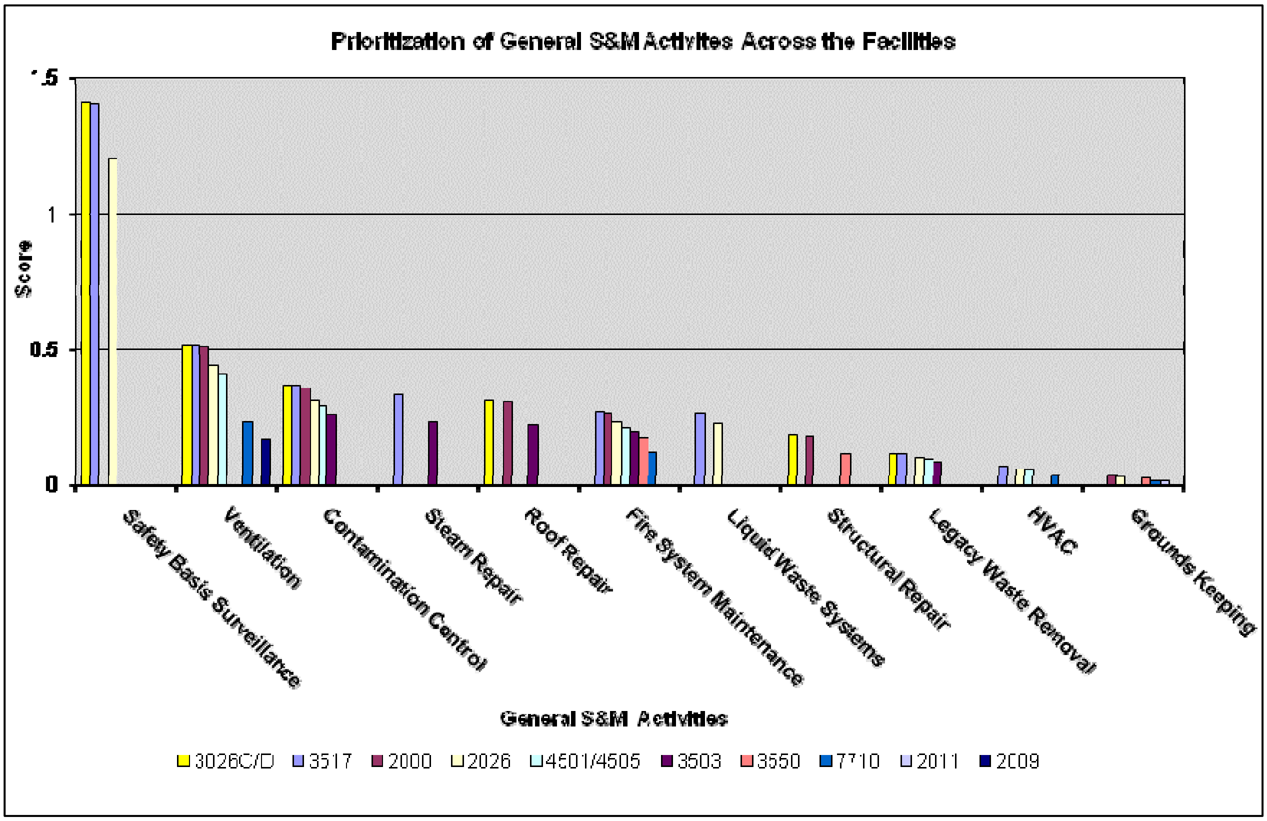

Fig. 3 Final prioritization of general S&M actions across 10 ORNL excess facilities

CONCLUSION

The Decision Support Tool can be a starting point to determine how to distribute S&M budgets, to help make consistent and risk-based decisions and to provide documentation for future reference and in addition, the tool is flexible enough to be modified and used at other DOE sites such as the Savannah River Site where the tool was introduced and received positive feedback. A team of S&M experts from the Savannah River Site have been introduced to the tool and are planning to test it with some of their facilities. The experts will be able to add or edit the criteria, revise the pair-wise assessment or insert a larger number of facilities based on any unique needs at their site.

Several factors which include the weights assigned to each criterion, the final rank of the facilities and the S&M actions are subject to the judgment of the decision maker. For this reason, a sensitivity analysis will be the next step to improve the decision tool. Further research on the applicability of this tool will lead to the development of a model to determine how much money should be spent in S&M and the possible consequences of delaying a maintenance action on the final cost of D&D.

REFERENCES

1. U.S. Department of Energy, Retrieved August 01, 2008 from http://www.doe.gov/environment/index.htm.

2. Hobbs B. F., 2000. *Energy Decisions and the Environment: A Guide to the Use of Multicriteria Methods.* Boston: Kluwer Academic Publishers. 6-8.

3. J.C. Watkins, L.S. Ghan. (1992). *AHP v.5.1 Users Manual.*(Idaho National Laboratory Technical Report EGG-ERTP-10585) Idaho Falls, Idaho. U.S. Nuclear Regulatory Commission.

4. Triantaphyllou, E., 2000. *Multi-Criteria Decision Making Methods: A Comparative Study*. The Netherlands: Kluwer Academic Publishers.