

SYSTEM FOR DECISION ANALYSIS SUPPORT ON COMPLEX WASTE MANAGEMENT ISSUES^a

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ABSTRACT

A software system called the Waste Flow Analysis has been developed and applied to complex environmental management processes for the United States Department of Energy (US DOE). The system can evaluate proposed methods of waste retrieval, treatment, storage, transportation, and disposal. Analysts can evaluate various scenarios to see the impacts to waste flows and schedules, costs, and health and safety risks. Decision analysis capabilities have been integrated into the system to help identify preferred alternatives based on a specific objectives. The objectives may be to maximize the waste moved to final disposition during a given time period, minimize health risks, minimize costs, or combinations of objectives. The decision analysis capabilities can support evaluation of large and complex problems rapidly, and under conditions of variable uncertainty. The system is being used to evaluate environmental management strategies to safely disposition wastes in the next ten years and reduce the environmental legacy resulting from nuclear material production over the past forty years.

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BACKGROUND

The system was developed in response to a US DOE need for a consistent basis for evaluating waste management methods which considers all aspects of waste management processes.

Systems Engineers and Software Scientists working at Idaho National Engineering and Environmental Laboratory (INEEL), located in the western U. S., have successfully developed and have implemented a nationwide software system called the Waste Flow Analysis. The system was developed using a proven Lockheed Martin Corporation systems engineering approach (see Figure 1). This approach consists of defining the problem, identifying alternatives, analyzing alternatives, choosing an alternative, implementing this alternative, and evaluating the results.

The Waste Flow Analysis covers the full waste management cycle: waste generation, interim process storage, retrieval, characterization and sorting, waste preparation and processing, waste packaging, transport, and final disposition.^b Scenarios in the system stem from actual Department of Energy streams of low-level waste, mixed low-level waste, transuranic waste, and high-level waste.

a. Work supported by the U.S. Department of Energy, Assistant Secretary for Environmental Management, under DOE Idaho Operations Office Contract DE-AC07-94ID13223.

b. Disposition can mean permanent disposal, long-term storage, or recycling.

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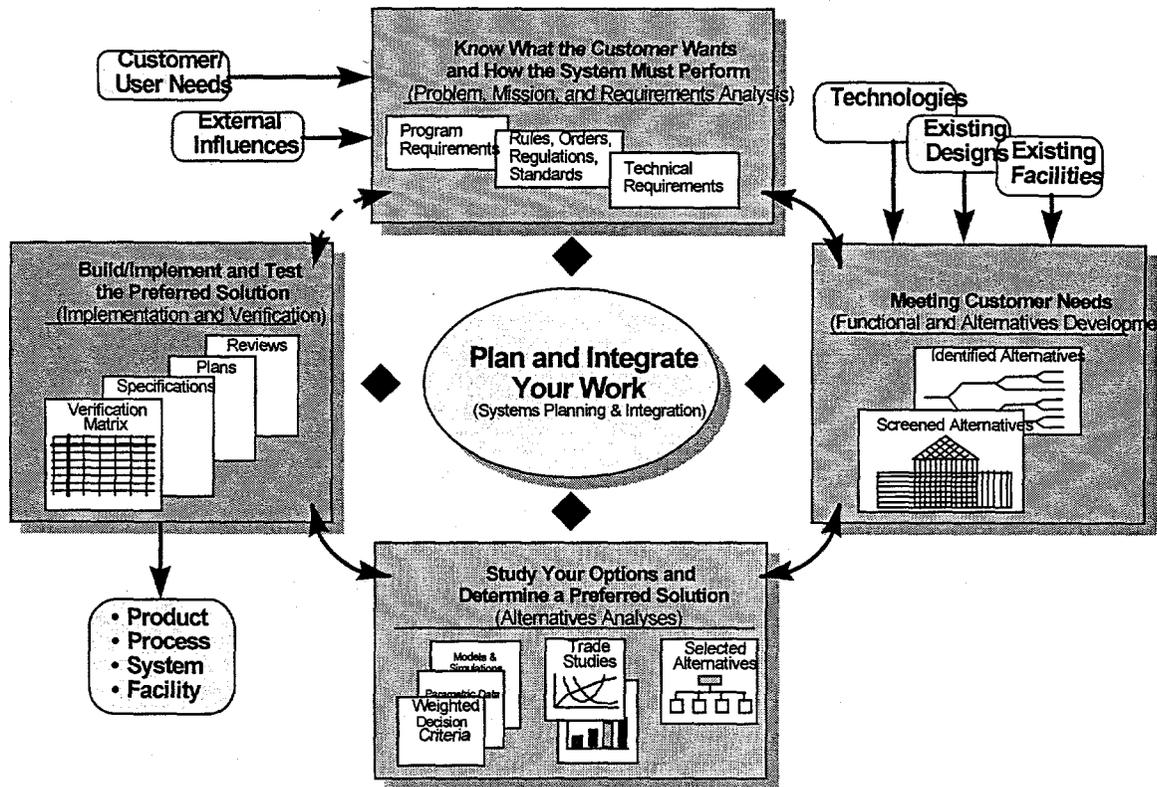


Figure 1. Lockheed Martin Corporation systems engineering approach.

Waste Flows and Schedules

The Waste Flow Analysis evaluates the impacts (in terms of costs, risks, and scheduling) from accelerations or delays in waste generation, pretreatment storage, treatment schedules, posttreatment storage, shipping, and final disposition. Waste flow/scheduling capabilities address the impact of:

- Varying waste flows on storage, transportation, and disposal.
- Future waste sources.
- Additional capacity availability (processing, storage, transportation).
- Extending processing operating schedules and earlier opening of disposal facilities.
- Improved waste processes and waste forms.
- Variations in waste separation and secondary waste production.
- Waste streams without a complete disposition path.

Waste flow/scheduling capabilities are used to evaluate the comparative ability of system alternatives to dispose of waste over a specific period of time. Figure 2 shows an example of an alternative using a new waste transport packaging system that can increase the speed with which waste can be moved to final disposition as compared to the Department of Energy's Ten-Year Plan (TYP) baseline.

Waste Disposition

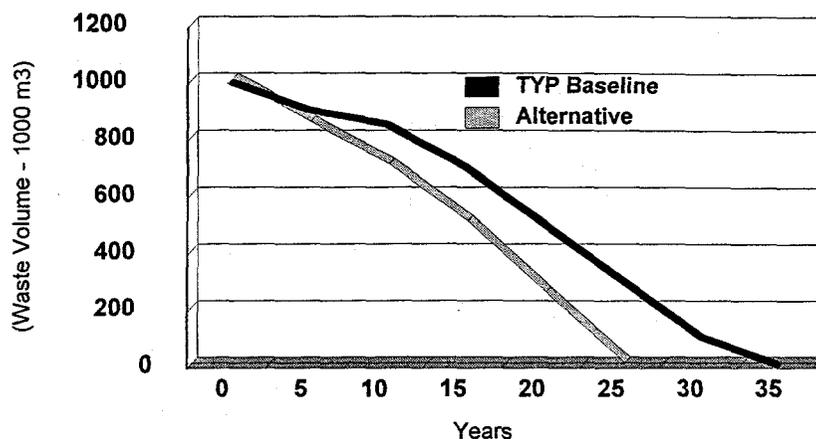


Figure 2. System waste disposition.

Transportation Analysis

The Waste Flow Analysis can be used to assess transportation alternatives between major waste generators, treatment and disposal sites, and commercial facilities. The system evaluates shipping rates and schedules, mileage and routes between facilities, packaging requirements, system throughput limitations, and process facility capacities. The system calculates the required quantity of transport packages and shipments.

The system can be used to assess the sensitivity of transportation flows to alternative waste processing schedules, transport modes, and packaging systems. Transportation throughput requirements are identified by route and waste type. The system can be used to identify the transportation capacities needed to meet the throughput and contingency needs to support changes in the system without creating transportation-related choke points. For example, the user can constrain the number of annual shipments of treated waste and then evaluate the impacts on storage and disposal. The user can also vary the treatment capacity or limit the availability of the number of shipment containers, trucks, and loading stations to identify impacts on a facility's receiving capabilities. Alternative packaging and transport mode options can be evaluated for potential reduction of impacts from transportation bottlenecks.

Transportation comparisons can be provided in terms of the total number of packages required to ship the wastes and the total number of shipments required. Figure 3 illustrates an example of a transportation comparison, where the alternative uses an improved package with higher waste loading than the base case, which reduces the number of packages and shipments required.

Cost Analysis

Waste Flow Analysis compares the costs of treatment/processing, storage, transportation, and final disposition. The system compares alternatives based on their ability to reduce the government's cost or mortgage liability to taxpayers. Mortgage liability is defined as the current total obligation of the U.S. government to safely dispose of hazardous wastes. The environmental cost legacy from nuclear weapons

Transportation Comparison

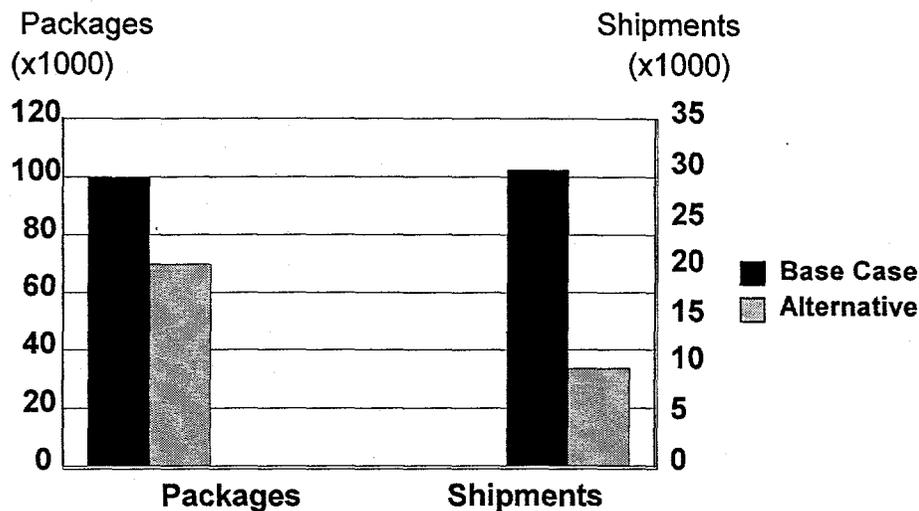


Figure 3. Transportation comparison.

production has been estimated in the hundreds of billions of dollars.^a This analysis technique is used to show how effective (compared with a baseline) an alternative may be at reducing the remaining mortgage cost. Rather than directly estimating life-cycle costs, this technique uses “cost” as a credit for performing treatment and waste disposition activities. The cost credit is defined at a standard cost per unit for each cubic meter of waste treated or dispositioned.^b As waste is treated and dispositioned, the total liability is reduced by the credited value of the treatment and disposition of the waste. Figure 4 provides an example of how an alternative is more effective than the baseline at reducing mortgage liability. The alternative incorporates higher utilization of existing DOE processing facilities and commercial sources, which results in accelerating the reduction in the mortgage liability.

Storage cost comparisons are used to complement the storage volume analysis capabilities. Storage costs are calculated based on a cost-per-cubic-meter-per-year basis. Due to the potential large differences in storage costs between waste types and DOE sites, storage costs provide an additional measure of the alternative’s effectiveness in minimizing interim storage.

Transportation cost comparisons are used to complement the Waste Flow Analysis transportation capacity analysis. Transportation costs include fixed (e.g., cost per shipment) and variable cost components (e.g., cost per loaded mile). The baseline costs are for shipment by road, with rail provided as an alternative means of conveyance when applicable.

a. *Estimating the Cold War Mortgage, The 1995 Baseline Environmental Management Report,* Vol. 1, March 1995, U.S. Department of Energy Office of Environmental Management.

b. Unit costs are derived from the DOE sites’ Ten Year Plans as of July 1996. The costs include appropriate facility capital, operations and maintenance expenses.

Mortgage Liability Reduction

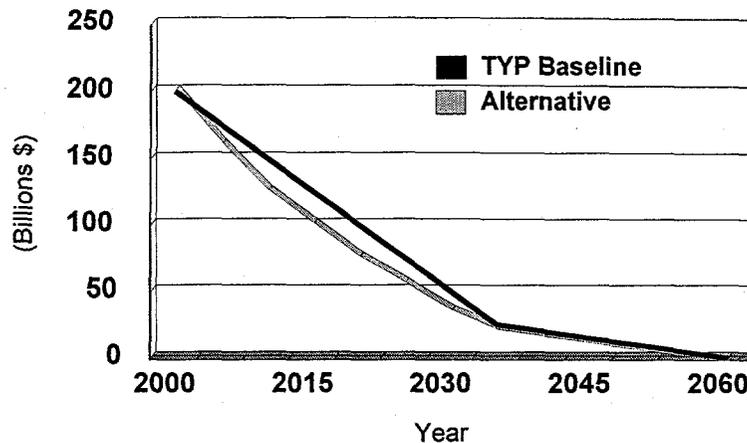


Figure 4. Mortgage liability reduction.

Relative Health and Safety Risks

Health and safety risk to workers and the public is calculated for each alternative. Health and safety risk is defined in DOE Order 5480.23 (DOE 1992a) as “the quantitative or qualitative expression of possible loss that considers both the probability that a hazard will cause harm and the consequences of that event.” A simplified method^a for quantitative assessment of the relative health and safety risk was developed to integrate environmental management activities. This method fills a gap between the purely qualitative methods (e.g., low, medium, high risk) and absolute risk methods (e.g., Safety Analysis Reports, Probabilistic Risk Assessments). This risk method satisfies the following five performance criteria:

1. Support consistent risk results for all waste types, including hazardous waste and mixed waste.
2. Include risk results for a full range of environmental management activities, including waste retrieval, treatment, storage, shipping, and disposal.
3. Can be used to provide rapid risk assessments.
4. Does not require large quantities of data or detailed descriptions of potential alternatives.
5. Is technically rigorous to the extent that the same general conclusions would be derived from comparing the risk of alternatives using absolute risk assessment methods.

a. T. H. Smith et al., *A Simplified Method for Quantitative Assessment of the Relative Health and Safety Risk of Environmental Management Activities*, INEL-96/0645, March 1996.

Waste Flow Analysis uses this risk method to help identify risk-reducing alternatives. The risk capability can be used to compare waste treatment systems, transportation and packaging, and storage and disposition. Figure 5 provides an example of an alternative using improved final waste forms and reduced worker waste handling to reduce the health and safety risk, as compared to the baseline.^a

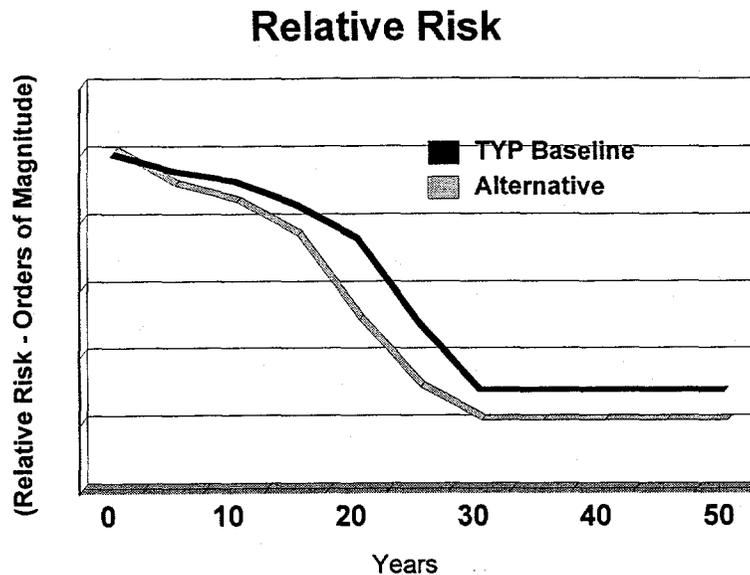


Figure 5. Health and safety risk reduction.

DECISION ANALYSIS

Decision analysis is a formal method of making decisions. It provides a logical framework for decision-making based on what one knows, is capable of doing, and prefers. Waste Flow Analysis includes decision analysis as a means of solving large and complex problems.

Objectives

Decision analysis utilizes linear programming algorithms to minimize or maximize an objective function within system constraints (e.g., transport package capacity limitations). Objective functions can include:

- Maximize waste moved to final disposition during a given period (e.g., 10 years).
- Minimize health and safety risk from transportation of waste.
- Minimize cost for treatment, storage, transportation, and disposition.

Decision analysis enables powerful insights into technology choices, scheduling issues, political and regulatory constraints, and negotiation positions.

a. The risk results shown on the y-axis represent orders of magnitude of relative risk. The risk results can be related to human dose (i.e., person-rem). Risk results include accident and normal risk to workers and the public.

Decision Trees

Decision analysis helps identify the best set of alternatives across waste types. Waste Flow Analysis sums the values of an objective function across all waste types.

The decision tree in Figure 6 shows an example of waste alternatives evaluated through decision analysis. Each of the four waste-type alternatives is placed on the decision tree. In this case, the total system was evaluated against the objective function of maximizing the waste moved to final disposition over a period of ten years. The highlighted branches of the decision tree show the optimal decision policy. In this example, the alternatives that best satisfy the objective function are high-level waste (HLW) alternative D, in combination with low-level waste (LLW) alternative B, mixed low-level waste (MLLW) alternative B, and transuranic waste (TRU) alternative A.

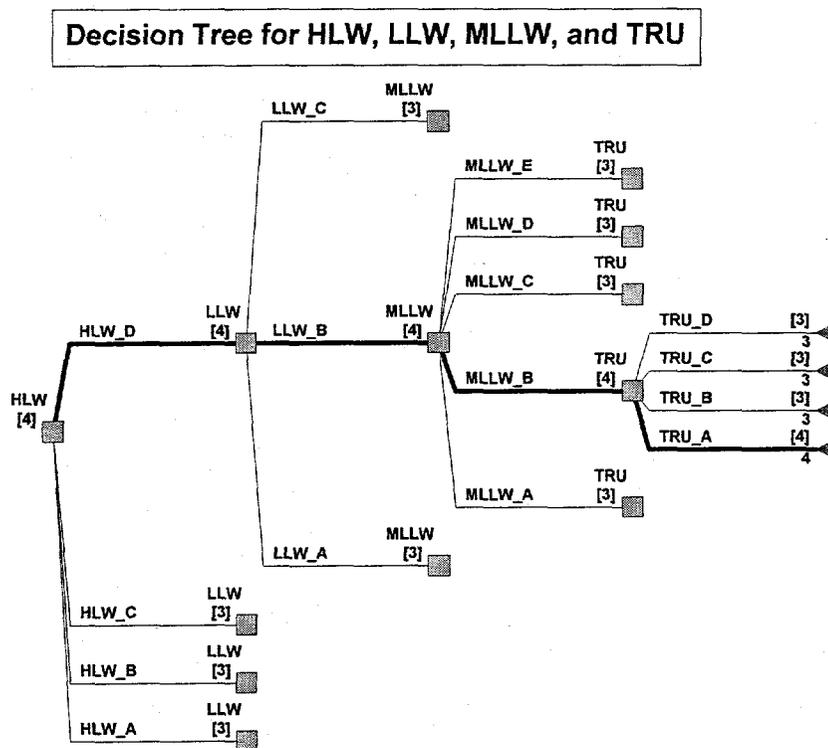


Figure 6. Decision tree.

Uncertainty Analysis

Decision analysis also provides the ability to perform variable uncertainty analysis. The tornado diagram in Figure 7 illustrates an example showing the impacts from four key variables (HLW volume reduction, TRU transport availability, MLLW treatment capacity, and LLW disposal input rate). Each of these variables was evaluated to determine minimum and maximum values.^a

a. Minimum and maximum points are selected where there is only 1 chance in 10 that the value of the variable could be lower or higher than the nominal value. These values are used to approximate a normal distribution.

Tornado Diagram

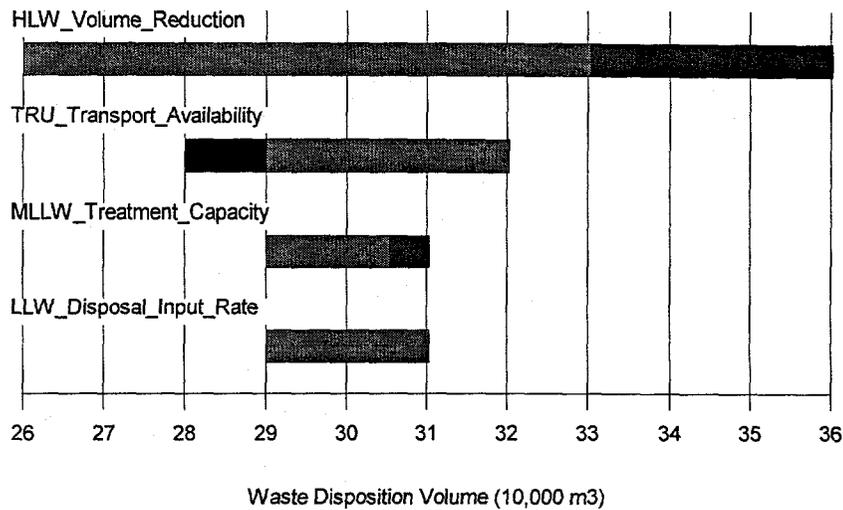


Figure 7. Tornado diagram.

In the example provided in Figure 7, the HLW volume reduction has the highest potential range of impact to the waste disposition volume. The volume could be as low as 260,000 m³ and as high as 360,000 m³. The shading on the right side of the bar indicates that a change to the decision policy will occur if the variable value is set at or near its maximum value. This means that at some variable value, the preferred alternative can change to a new alternative. Further decision analysis can be performed to determine the exact value of the variable if the decision policy changes to the new preferred alternative.

CONCLUSION

The Waste Flow Analysis system is an effective way to evaluate waste management alternatives. The Waste Flow Analysis program leads to improved waste management technologies and system integration, thus reducing waste management costs and risks.

The system evaluates (a) alternatives that consolidate waste treatment, storage, and disposal, (b) new waste packaging and transportation systems, (c) tradeoffs between processing and treatment systems, (d) impacts from environmental restoration land-use policies, and (e) various strategic and technology development studies.

Waste Flow Analysis embodies a decision analysis capability to rapidly evaluate complex problems. Decision analysis identifies and integrates the best combination of waste management alternatives.