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ADDRESSING MIXED WASTE IN PLUTONIUM PROCESSING

INTRODUCTION

For the past forty years, multiple facilities throughout the Department of Energy (DOE) Complex have produced nuclear weapons, processed recoverable residues, and generated a variety of waste materials. Today, the Complex is comprised of 13 government-owned and contractor-operated installations. It is organized into three functional elements: facilities for producing nuclear materials, laboratories and testing sites, and plants for producing non-nuclear components. Although these facilities have always been concerned with waste products and materials, the evolution of tougher regulations and stiffer penalties along with escalating costs of waste disposal has produced a greater focus on the waste minimization and management problem.

In the processing of nuclear materials, several types of waste forms exist that include both radioactive and non-radioactive elements. Wastes can be considered hazardous if (1) they are specifically listed by the Environmental Protection Agency (EPA) as hazardous, or (2) they exhibit a special characteristic such as corrosivity or toxicity. If a waste is hazardous, the EPA has stricter requirements regarding its characterization treatment, storage, and burial, thereby increasing the disposal cost to its generator. A major concern today is with "mixed waste" which has been defined by the EPA as a radioactive waste with a hazardous component that is subject to the EPA's Resource Conservation and Recovery Act (RCRA), subtitle C regulations.

Within the DOE Complex, mixed waste is or has been generated at the production facilities at Pinellas, Mound, Kansas City, Y-12, Rocky Flats, Savannah River, and Pantex; the National Laboratories at Los Alamos, Sandia, and Livermore; and the Nevada Test Site. Since DOE did not recognize the EPA's participation in the management of mixed waste until 1987, it is considered to be a relatively new concern.

METHODOLOGICAL APPROACH

Although an overall goal is the minimization of all waste generated in actinide processing facilities, current emphasis is directed toward reducing and managing mixed waste in plutonium processing facilities. More specifically, the focus is on prioritizing plutonium processing technologies for development that will address major problems in mixed waste management.

A five step methodological approach to identify, analyze, solve, and initiate corrective action for mixed waste problems in plutonium processing facilities has been developed. A brief description of this approach follows:

1. Identify the Major Problems in Mixed Waste Management at Plutonium Processing Facilities:
    a. Develop a process flow sheet that describes current product fabrication, scrap recovery, and waste minimization and management operations.
    b. Identify specific mixed waste management goals for processing facilities.
    c. Compare current performance with desired performance in mixed waste management.
    d. Problems are indicated when there is a discrepancy between actual and desired performance.

2. Prioritize the Major Problems:

   a. Identify criteria to be used in establishing problem priorities.

   b. Use the pairwise comparisons feature in EXPERT CHOICE (EC)* on the criteria to assign importance weights to each criterion.

   c. Use EC to compute problem priorities through pairwise comparison of each problem relative to each criterion.

3. For the Problem with the Highest Priority:

   a. Identify between 2 and 5 alternative solution technologies.

   b. Specify relevant criteria for evaluating the effectiveness of the alternative solution technologies.

   c. Use EC (pairwise comparisons) to assign importance weights to criteria.

   d. Use EC to rank alternative problem solutions through pairwise comparison.

4. Repeat Step 3 for Each of the Major Problems

5. Develop and evaluate a process flow sheet that incorporates the most desired solutions to all of the major problems identified in step 3 above.

   a. Create and validate an analytical model to imitate the behavior of the new process flow sheet.

   b. Use the model to test the new process configuration for operational feasibility and potential material flow bottlenecks by running a variety of "what-if" scenarios.

   c. Use the results of the modeling exercise to modify the proposed flow sheet.

   d. Implement the resultant flow sheet which promotes an integrated set of plutonium fabrication, scrap/residue recovery, and waste minimization/management processes.

Several advantages are associated with the use of this methodological framework. First, an operational definition of a mixed waste problem is provided in step 1. That is, a problem

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* EXPERT CHOICE (EC) is an user-friendly software package for implementing the Analytic Hierarchy Process methodology used in solving complex problems involving multiple performance criteria.

exists when current levels of performance in waste management are below stated goals for the processing facility. Both the amount of the performance discrepancy and the type of mixed waste involved should be used when determining whether or not to label a problem as "major". Second, since there is always a limited amount of managerial time and energy available for problem solving, a systematic procedure to determine problem priorities is desirable. Third, a quantitatively-based method for aggregating the rankings of different performance criteria on alternative solutions to the major problems will increase the probability of selecting the best alternative. Finally, the use of an analytically-based integrated model to assess the overall flowsheet performance of all the best solution alternatives allows the linkages or interfaces between proposed facility processes to be evaluated before implementation occurs.

The interrelationships between the these five steps are diagrammatically illustrated in Figure 1. It is important to note the iterative nature of this approach, as depicted in the third and fourth steps, for prioritizing the effectiveness of members of a set of alternative process technologies for a particular problem. This focus on the selection and/or development technologies for the solution of mixed waste problems is a key characteristic of this problem-driven methodology.

The use of the Analytic Hierarchy Process (AHP) is also supportive of this problem-oriented methodological focus. Basically, AHP is a method for structuring a complex decision making problem into its component parts; arranging these parts into a hierarchic order; assigning quantitative scores that measure the relative importance of each criteria on the decision goal; and synthesizing the analytical assessments into an aggregated performance measure for each of the competing alternative solutions. EXPERT CHOICE (EC) is an user-friendly software package for implementing AHP methodology. Since most problems involved multiple (tangible and intangible) criteria, EC was used to enforce a cohesive thought pattern on the part of the analysts as they seek to identify the best alternative.

The next section illustrates the use of the EC computer software package to develop weights for the various performance criteria according to their perceived importance, systematically evaluate all alternative processes against each criterion, and aggregate the individual criteria scores into a composite performance measure for each of the candidate process technologies.

AN ILLUSTRATION

Assume that newly defined waste management goals have been developed for the LANL plutonium processing facility. Current performance levels indicate that the goal for mixed waste generation is not being met. This problem is to be addressed by selecting a metal shaping process that will reduce the generation of mixed waste. Each of the components of step 3 are illustrated for this scenario.

Step 3a. Three alternative metal shaping solution technologies:

1. Wrought Process
2. Near Net Shape Casting
3. Net Shape Casting

The wrought process involves taking flat plates of plutonium and rolling them into sheets. The sheets are then hydroformed into the desired hemispherical shape. Both the rolling and the hydroforming processes involve the use of machine oils as lubricants with the subsequent requirement to clean off the oils with organic solvents such as carbon tetrachloride. Finally, the hemispherically-formed components are processed to final contour employing the traditional machining techniques which use flood-cooling of the component with oil-based coolants. The oil flood cooling approach requires the use of large amounts of solvents to remove the oil from the final machined components as well as from the glovebox enclosures and processing equipment.

An alternative technology, the near net shape casting process, utilizes the direct casting of plutonium into the required hemispherical shape followed by the machining. This processing alternative avoids the need to roll and hydroform. Although there is a significant reduction of mixed waste on an unit operation level, the impact on the mixed waste generation and disposal problem is fairly modest.

The third fabrication technique, net shape casting, involves casting the plutonium very closely to the final specified contour so that rolling, hydroforming, and most of the machining operations are eliminated. Again, the generation of mixed waste is further reduced, although from an overall plant perspective, the improvement is modest. Since this technology is relatively new and still evolving, there is more uncertainty surrounding its reported performance than that associated with the two former alternatives. Thus, even though it appears to produce the smallest amount of mixed waste, it may be inappropriate to conclude it is the best metal shaping process.

Although each of the three technologies could be used for forming the required plutonium components and each has both desirable and undesirable attributes, it is not obvious which should be selected. AHP provided an organized framework for systematically evaluating the preferred alternative.

Step 3b. Three relevant criteria:

1. Amount of Mixed Waste Generated

Four Subcriteria each representing one of the four types of mixed waste generated:

a) Kg of Low Level Solid Mixed Waste per kg of metal produced

b) Kg of TRU Solid Mixed Waste per kg of metal produced

c) Kg of Low Level Liquid Mixed Waste per kg of metal produced

d) Kg of TRU Liquid Mixed Waste per kg of metal produced

2. Difficulty in Disposing of Mixed Waste that is Generated

Five Subcriteria each associated with minimizing the impact of mixed waste disposal:

a) Technical Maturity - the more technically mature the metal shaping process, the greater the confidence in the validity of the waste estimates presented.

b) Complexity - the greater the number of different types of mixed waste generated by a metal shaping process, the more complex the required mixed waste disposal infrastructure.

c) Flexibility - the greater the flexibility of the metal shaping process, the more likely the process will be able to respond to new mixed waste requirements.

d) Health and Safety - the primary concern is to minimize the potential radiation and chemical exposure of personnel involved in the mixed waste disposal process.

e) Costs - the processing costs of mixed waste disposal are assumed to be directly related to the amount of mixed waste generated.

3. Public Perception of Mixed Waste Generation and Disposal Problem

Three Subcriteria each related to an aspect of mixed waste disposal:

a) Transportation - the travel route and its usage frequency for transporting mixed waste from its generating source to its final destination.

b) Ultimate Disposal Destination - the location and containerization method of the final burial site for generated mixed waste.

c) Packaging - the ability of the transport container to remain intact in case of an accident during the movement of mixed waste to its disposal destination.

Figure 2 displays the hierarchical ordering of these criteria as they relate to the overall goal of identifying the metal shaping process that will produce the minimal impact on mixed waste generation and disposal. By reducing a problem into its elements and grouping these elements at different levels, a hierarchy is formed. Weights reflecting the relative importance of each criteria (and subcriteria) can then be assigned by performing pairwise comparisons at each level in the criteria hierarchy. As previously mentioned, this AHP modeling structure is especially effective when a variety of different types of criteria, some quantitative and some qualitative, must be aggregated into an overall score to rank each solution alternative.

<u>Step 3c.</u> Establishing Criteria/Subcriteria Weights:

As shown in Figure 2, the relative importance of the three major criteria was determined. Public perception of the mixed waste problem was thought to be four times as important as the difficulty in disposing of the mixed waste and over twice as important as the actual amount of waste that is generated. Since quantitative data were available on the costs associated with disposing of an unit of each type of mixed waste, they were used to determine the weights for the four different types of mixed waste generated. In contrast, pairwise comparisons based on expert judgements were used to determine the priorities associated with each of the five subcriteria related to mixed waste disposal difficulty. Finally, the relative importance of each of the three dimensions thought to be related to the public's perception of the mixed waste problem was subjectively evaluated by the analysts. The results of these evaluations are shown in Figure 3.

Step 3d. Ranking Alternative Solution Technologies Against the Criteria/Subcriteria:

Numerical estimates are made of the amounts of mixed waste that are generated by each of the competing metal shaping technologies. Since less rather than more mixed waste is preferred, the inverse of these amounts was directly used to ascertain the preference of each technology relative to each of the four subcriteria under "Amount of Mixed Waste Generated". Again, expert judgement, through the pairwise comparison technique, was used to rank the desirability of each alternative technology relative the five "Difficulty in Disposing of the Mixed Waste Generated" subcriteria. It is interesting to note that the performance of the three technologies was assessed as equal for the three "Public Perception" subcriteria, that is, it is assumed the public is indifferent about which metal shaping technology is used to generate mixed waste. The results of the synthesizing procedure indicate that the alternatives are about equally preferred:

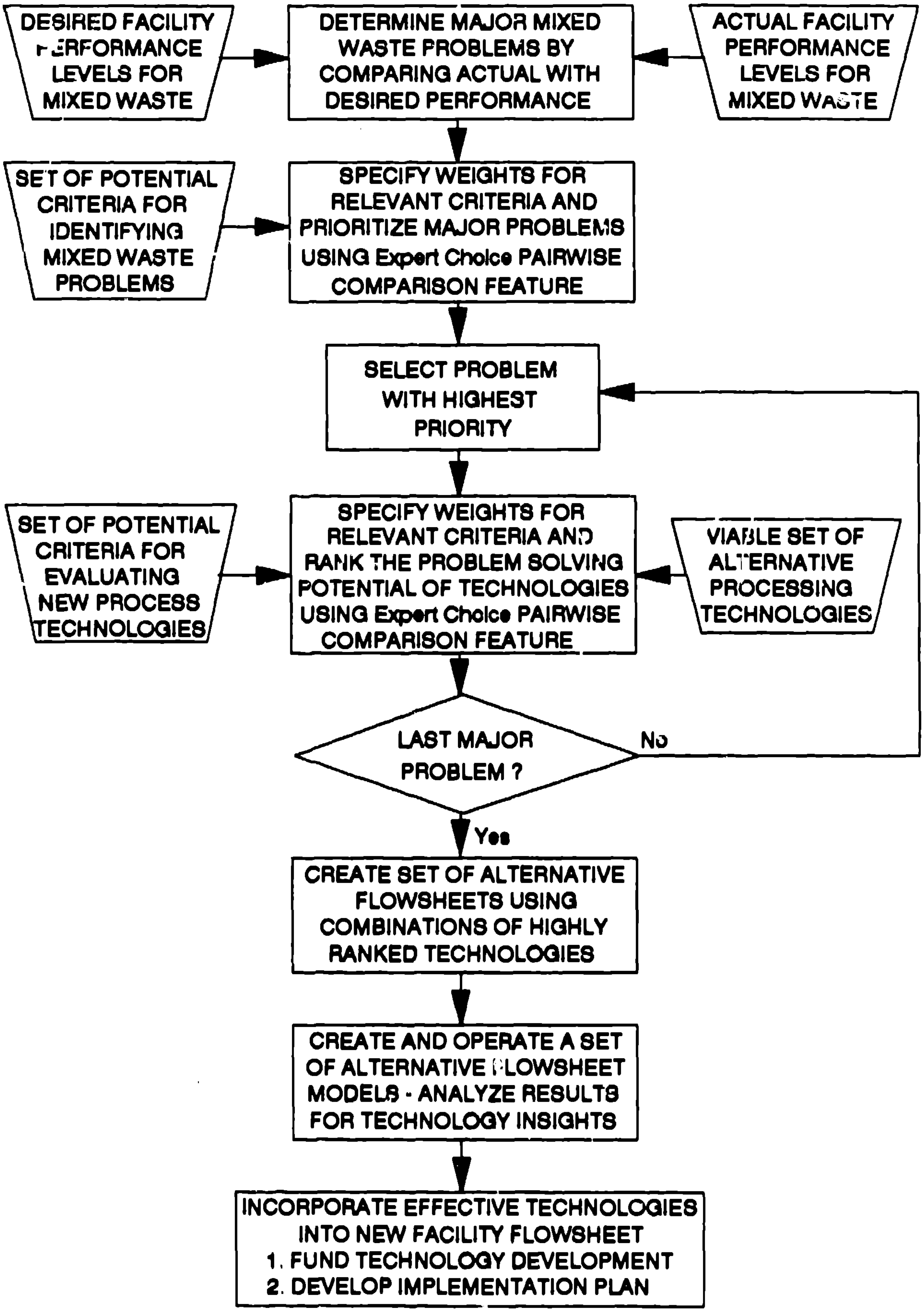
Wrought Casting = .309
Near Net Shape Casting = .331
Net Shape Casting = .360.

Since the alternative technology scores are relative close, it is important to examine EC's built-in sensitivity analyses. The performance of each of the alternative technologies is graphically displayed in Figure 4. It is noteworthy that Net Shape Casting achieves its overall preference through its higher ranking in the first criterion, Amount of Mixed Waste Generated, even though this criteria has only a 0.25 weight.

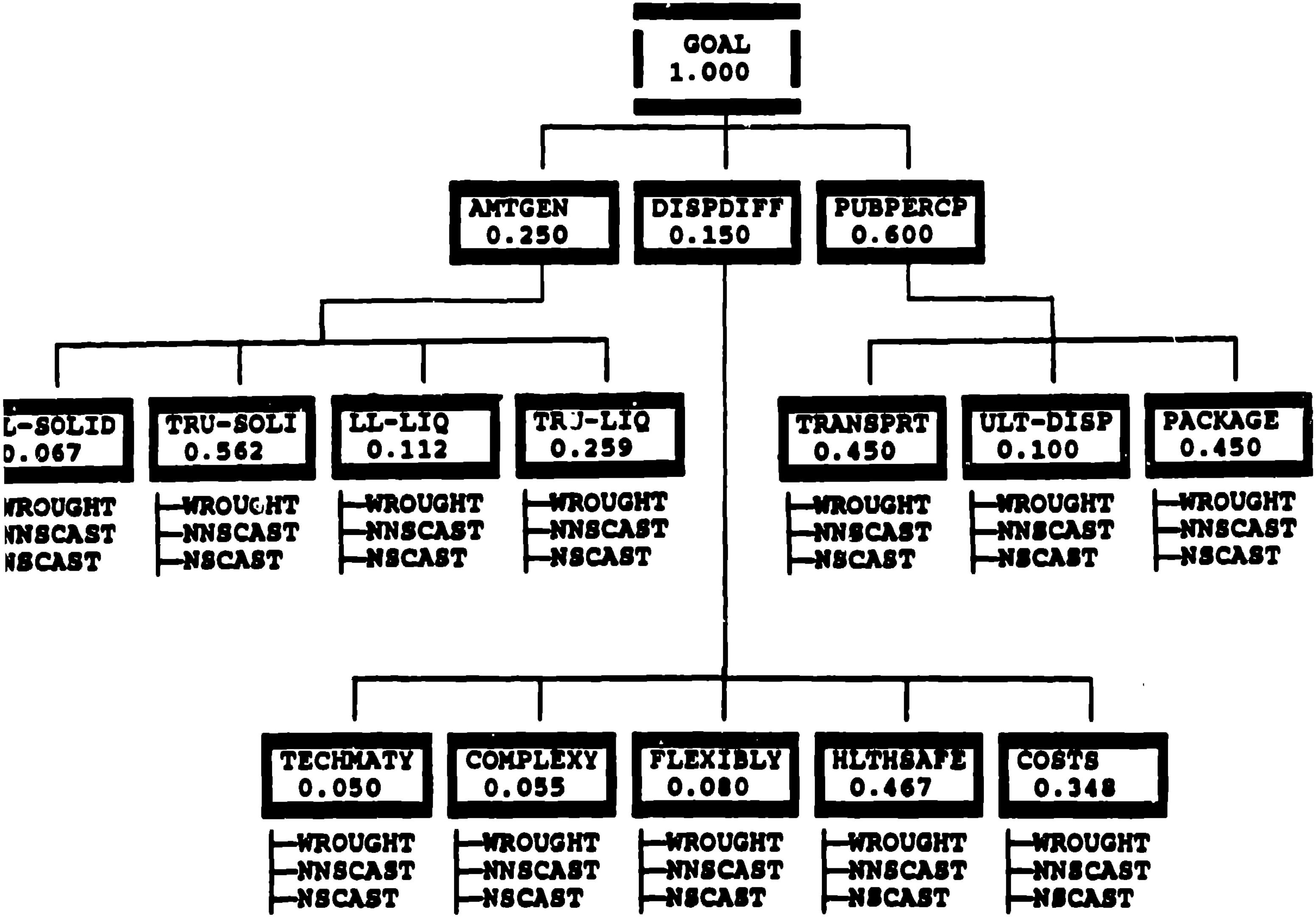
SUMMARY AND CONCLUSIONS

If the mixed waste generation and disposal situation was the only major problem, it would be appropriate to recommend that the Net Shape Casting process be incorporated into a new process flow sheet for the plutonium processing facility. Before implementing a plan to remove the current metal shaping process and install Net Shape Casting, however, it is necessary to imitate facility performance with a model. A computer-based dynamic simulation model will allow a test of the new process configuration under a number of different operational configurations and material flows. If the employment of the new metal shaping process had some undesirable effects on other measures of facility performance, then the behavior of the second ranked process, Near Net Shape Casting, would be modeled before a final decision for implementation could be determined.

LIST OF FIGURE TITLES . . . . .


DESIRED FACILITY PERFORMANCE LEVELS FOR MIXED WASTE
DETERMINE MAJOR MIXED WASTE PROBLEMS BY COMPARING ACTUAL WITH DESIRED PERFORMANCE
ACTUAL FACILITY PERFORMANCE LEVELS FOR MIXED WASTE
SET OF POTENTIAL CRITERIA FOR IDENTIFYING MIXED WASTE PROBLEMS
SPECIFY WEIGHTS FOR RELEVANT CRITERIA AND PRIORITIZE MAJOR PROBLEMS USING Expert Choice PAIRWISE COMPARISON FEATURE
SELECT PROBLEM WITH HIGHEST PRIORITY
SET OF POTENTIAL CRITERIA FOR EVALUATING NEW PROCESS TECHNOLOGIES
SPECIFY WEIGHTS FOR RELEVANT CRITERIA AND RANK THE PROBLEM SOLVING POTENTIAL OF TECHNOLOGIES USING Expert Choice PAIRWISE COMPARISON FEATURE
VIABLE SET OF ALTERNATIVE PROCESSING TECHNOLOGIES
LAST MAJOR PROBLEM ?
No
Yes
CREATE SET OF ALTERNATIVE FLOWSHEETS USING COMBINATIONS OF HIGHLY RANKED TECHNOLOGIES
CREATE AND OPERATE A SET OF ALTERNATIVE FLOWSHEET MODELS - ANALYZE RESULTS FOR TECHNOLOGY INSIGHTS
INCORPORATE EFFECTIVE TECHNOLOGIES INTO NEW FACILITY FLOWSHEET
1. FUND TECHNOLOGY DEVELOPMENT
2. DEVELOP IMPLEMENTATION PLAN

SELECT METAL SHAPING PROCESS TO MINIMIZE IMPACT OF MIXED WASTE

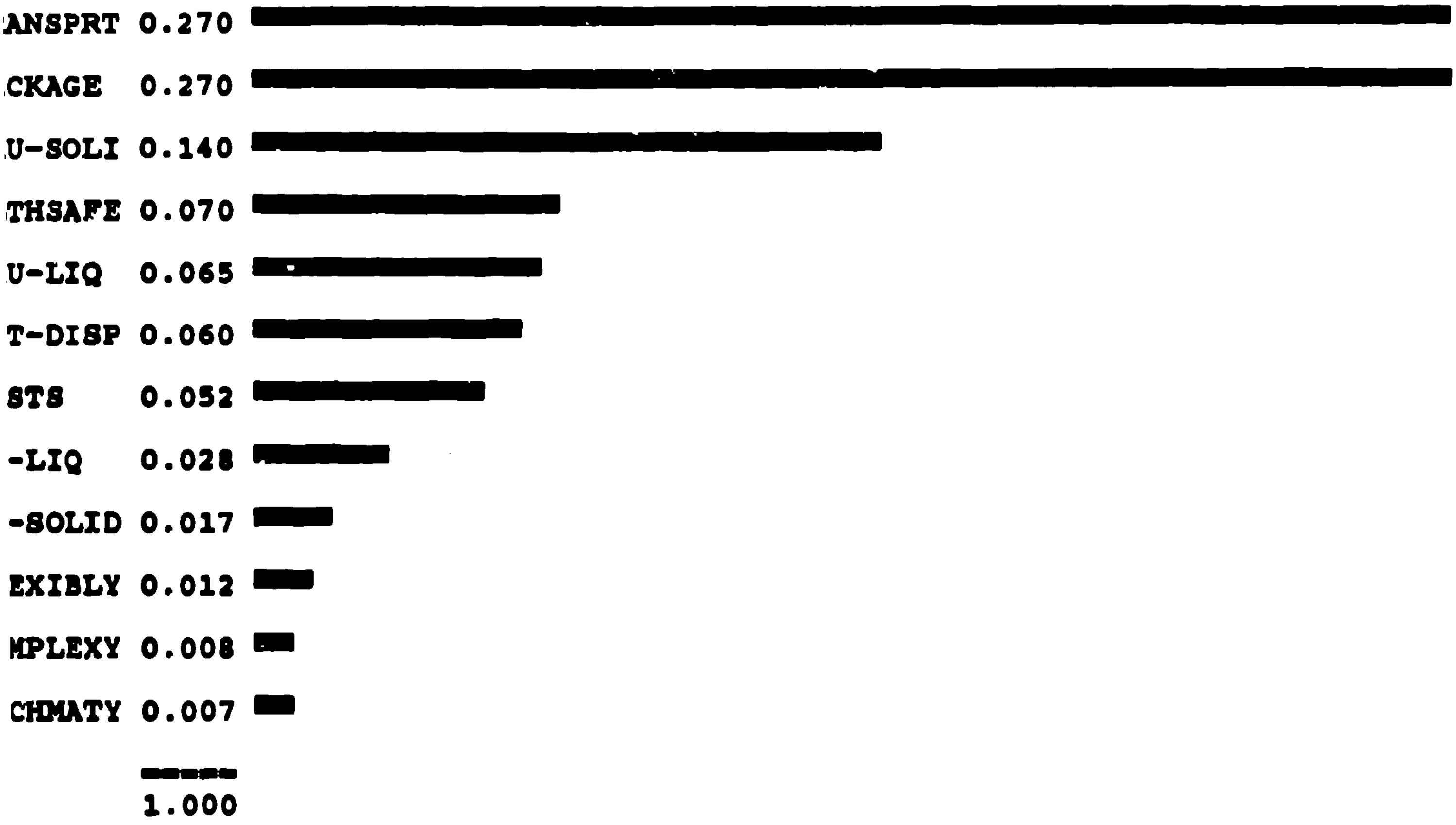


TGEN --- AMOUNT OF MIXED WASTE TO BE GENERATED / KG OF METAL PRODUCED
MPLEXY --- DISPOSAL COMPLEXITY = f(NUMBER OF TYPES MIXED WASTE GENERATED)
STS --- ASSUME DISPOSAL COSTS ARE DIRECTLY RELATED MIXED WASTE AMT GEN
SPDIFF --- DIFFICULTY IN DISPOSING OF MIXED WASTE
EXIBLY --- FLEXIBILTY OF CASTING PROCESS TO MEET NEW MIXED WASTE REGULATIONS
THSAFE --- ABILITY OF MIXED WASTE DISPOSAL PROCESS TO MIN. WORKER EXPOSURE
-LIQ --- LOW LEVEL MIXED LIQUID WASTE (LT) GENERATED / METAL PRODUCED (KG)
-SOLID --- LOW LEVEL SOLID MIXED WASTE (KG) GENERATED / METAL PRODUCED (KG)
SCAST --- NEAR NET SHAPE CASTING
CAST --- NET SHAPE CASTING
CKAGE --- PACKAGE OR CONTAINER USED TO TRANSPORT MIXED WASTE
BPERCP --- PUBLIC PERCEPTION OF MIXED WASTE GENERATION AND DISPOSAL PROBLEM
CHMATY --- DEGREE OF CONFIDENCE IN ESTIMATES OF MIXED WASTE GENERATED AMOUNT
ANSPRT --- TRANSPORTATION CONCERNS--ROUTE AND TRUCK USAGE FREQUENCY
U-LIQ --- TRU MIXED LIQUID WASTE (LT) GENERATED / METAL PRODUCED (KG)
U-SOLI --- TRU SOLID MIXED WASTE (KG) GENERATED / METAL PRODUCED (KG)
T-DISP --- ULTIMATE DISPOSAL (BURIAL) SITE LOCATION
OUGHT --- WROUGHT CASTING

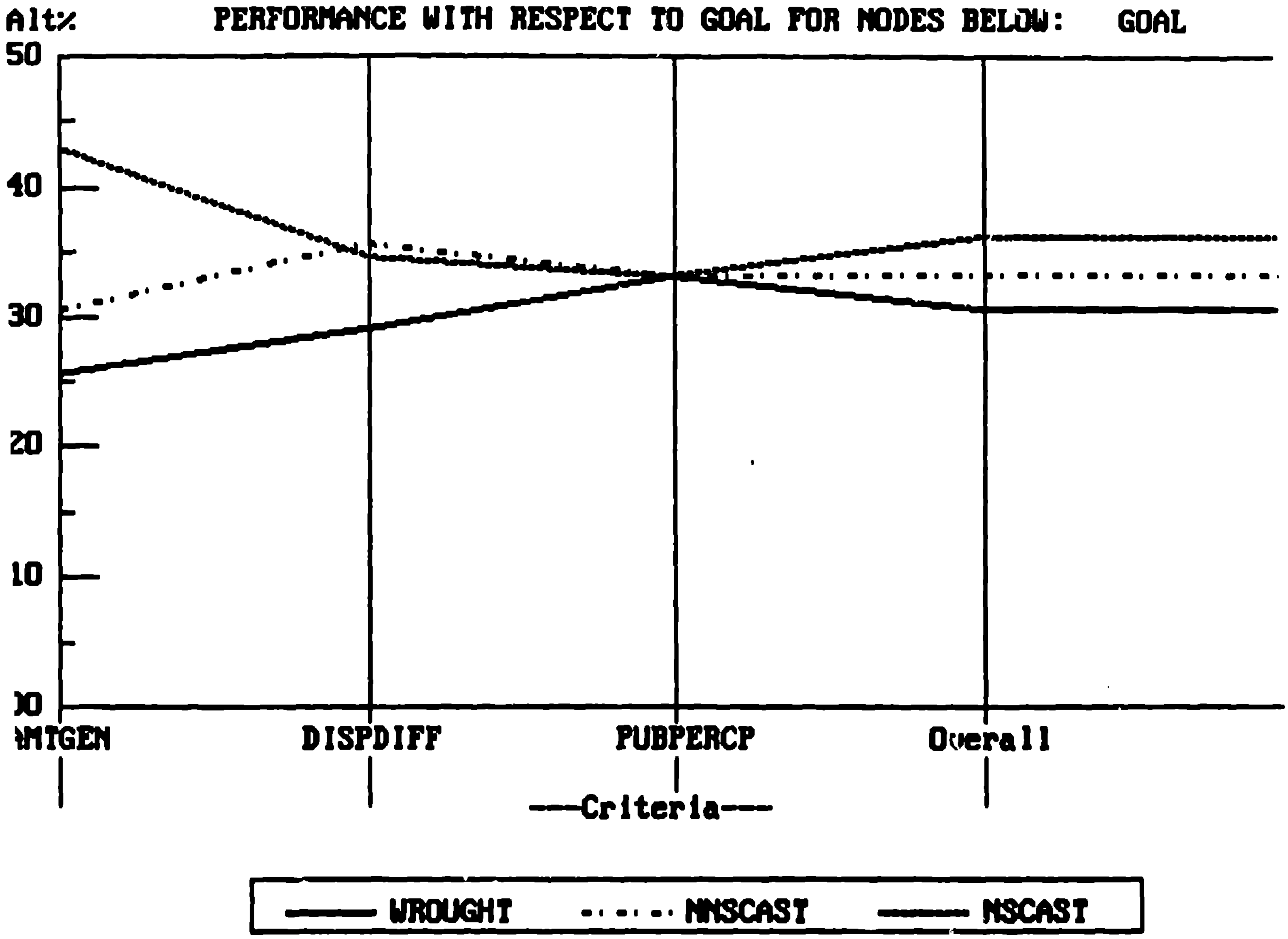
SELECT METAL SHAPING PROCESS TO MINIMIZE IMPACT OF MIXED WASTE

Sorted Synthesis of Level 2 Nodes with respect to GOAL

OVERALL INCONSISTENCY INDEX = 0.00



MPLEXY --- DISPOSAL COMPLEXITY = f(NUMBER OF TYPES MIXED WASTE GENERATED)
STS --- ASSUME DISPOSAL COSTS ARE DIRECTLY RELATED MIXED WASTE AMT GEN
EXIBLY --- FLEXIBILTY OF CASTING PROCESS TO MEET NEW MIXED WASTE REGULATIONS
THSAFE --- ABILITY OF MIXED WASTE DISPOSAL PROCESS TO MIN. WORKER EXPOSURE
-LIQ --- LOW LEVEL MIXED LIQUID WASTE (LT) GENERATED / METAL PRODUCED (KG)
-SOLID --- LOW LEVEL SOLID MIXED WASTE (KG) GENERATED / METAL PRODUCED (KG)
CKAGE --- PACKAGE OR CONTAINER USED TO TRANSPORT MIXED WASTE
CHMATY --- DEGREE OF CONFIDENCE IN ESTIMATES OF MIXED WASTE GENERATED AMOUNT
ANSPRT --- TRANSPORTATION CONCERNS--ROUTE AND TRUCK USAGE FREQUENCY
U-LIQ --- TRU MIXED LIQUID WASTE (LT) GENERATED / METAL PRODUCED (KG)
U-SOLI --- TRU SOLID MIXED WASTE (KG) GENERATED / METAL PRODUCED (KG)
T-DISP --- ULTIMATE WASTE DISPOSAL SITE LOCATION & CONTAINERIZATION METHOD



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