Summary of Computational Support
and General Documentation for Computer Code (GENTREE)
Used in Office of Nuclear Waste Isolation
Pilot Salt Site Selection Project

6 December 1983

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ABSTRACT

A Decision Tree Computer Model was adapted for the purposes of a Pilot Salt Site Selection Project conducted by the Office of Nuclear Waste Isolation (ONWI). A deterministic computer model was developed to structure the site selection problem with submodels reflecting the five major outcome categories (Cost, Safety, Delay, Environment, Community Impact) to be evaluated in the decision process. Time-saving modifications were made in the tree code as part of the effort. In addition, format changes allowed retention of information items which are valuable in directing future research and in isolation of key variabilities in the Site Selection Decision Model. The deterministic code was linked to the modified tree code and the entire program was transferred to the ONWI-VAX computer for future use by the ONWI project.

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1.0 INTRODUCTION

A major part of the Lawrence Livermore National Laboratory (LLNL) role in the Salt Site Selection Project for the Office of Nuclear Waste Isolation (ONWI) was focused on adapting and developing certain aspects of the Decision Tree computer code, described in this report. For the purposes of this project, a code previously developed at Stanford Research Institute (SRI) was modified to include the special requirements of the project. As each of the deterministic submodels in the Decision Analysis Program, described in the accompanying report (Yunker and Yunker, 1983) are run, the data items are provided for specified paths connecting chance and decision nodes. Sensitivity studies during the deterministic phase of the study were used to limit the number of nodes and pathways so that all possible conditions are not specified, only those where sensitive variables are included.

To improve the code and adapt it to current ONWI needs, time-saving modifications were made as part of the LLNL task. Coalescence was added so that common portions of paths through the decision tree are preserved and called when needed, rather than recalculating the node and path values for each run. Other format and program changes allow complete path printouts, and value of information calculations, which allow an assessment of the effect of reduction of uncertainty in key data items. This is very valuable for directing research in a developing program, and for isolating key critical parameters which significantly influence the difference between alternatives in the decision process.

The following sections provide an overview of the procedures for running the EVAL (evaluation of tree) and GENTREE (generates decision tree). Node names are defined, and terminal reward indices are specified. A glossary of nodes in GENTREE which are used to form the Tree is provided. Probabilities and rewards for each node are identified, and an accounting of the total number of Endnodes for each scenario is provided.

2.0 HOW TO RUN EVAL FOR THE SALT SITE PROBLEM

The program EVAL evaluates the tree generated by GENTREE. Following is a listing of the chance and decision nodes, together with the number of successor nodes.

2.1 NODE NAMES: Eight character names are used by EVAL to identify nodes.

2.1.1 Decision nodes:

Primary site - "PRIMARY ", 3 successors

Secondary site - "SECOND ", 2 successors

2.1.2 Chance nodes:

Mix scenario - "MIX ", 2 successors

Site characterization - "SITECHAR", 4 successors

Exploratory shaft result - "SHAFTRES", 2 successors

Abandon salt or build - "ABANDON ", 2 successors

Build primary site - "BUILD1 ", 1 successor

Build at second site - "BUILD2 ", 1 successor

Build at third site - "BUILD3 ", 1 successor

Operations delay - "OPDELAY ", 1 successor

2.1.3 Chance nodes with probabilities that vary by site:

Preconstruction delay - "PRECON1 " for Gulf, 3 successors

"PRECON2 " for Permian, 3 successors

"PRECON3 " for Paradox, 3 successors

Construction delay - "CONDEL1 " for Gulf, 2 successors

"CONDEL2 " for Permian, 2 successors

"CONDEL3 " for Paradox, 2 successors

Labor people-years multiplier - "LABORYR1" for Gulf, 3 successors

"LABORYR2" for Permian, 3 successors

"LABORYR3" for Paradox, 3 successors

Labor hourly wage multiplier - "LABORWG1" for Gulf, 2 successors
"LABORWG2" for Permian, 2 successors
"LABORWG3" for Paradox, 2 successors

R & D cost multiplier - "R AND D1" for Gulf, 2 successors
"R AND D2" for Permian, 2 successors
"R AND D3" for Paradox, 2 successors

2.2 MENU: SELECTION OF OPTIONS AVAILABLE

Following is a list of the questions EVAL asks the user and the responses needed to get the desired set of results out of it. Each response is discussed in more detail in the next section.

- a PROBLEM NAME (MAX 7 CHAR)
- b USE A SUBTREE (Y OR N)
- c BASE RISK AVERSION COEFFICIENT
- d DECISION PRINTOUTS (Y OR N)
- e LOTTERY DISPLAY (Y OR N)
- f SPECIAL TERMINAL LOTTERIES (Y OR N)
- g ENDPOINT PATH PRINTOUT (Y OR N)
- h RISK SENSITIVITY (Y OR N)
- i VALUE OF INFORMATION (Y OR N)
- j FORCE SUCCESSORS (Y OR N)
- k SENSITIVITY ANALYSIS (Y OR N)
- l REWRITE MENU

2.3 PROBLEM NAME (7 char max): SALTRUN [This must match the name given when GENTREE was run.]

2.3.1 QUESTION NUMBER (0 TO EXIT): 2

Use a subtree (Y or N): Y

Enter name of subtrees start node: PRIMARY [This runs just the spent fuel half of the tree. Enter 2 for reprocessing.]

If several nodes of same name, enter count to desired node (otherwise enter 1): 1

2.3.2 QUESTION NUMBER (0 TO EXIT): 3

Base risk aversion coefficient: 0.001

2.3.3 QUESTION NUMBER (0 TO EXIT): 4

Decision printouts (Y or N): Y

Active only (Y or N): Y

2.3.4 QUESTION NUMBER (0 TO EXIT): 5

Lottery display (Y or N): Y

Printout (Y or N): Y

Plot (Y or N): Y

2.3.5 POST-CLOSURE NODES (NOT CURRENTLY BEING USED):

Solution mining - "SOLUTION", 4 successors

Aquifer scenario - "AQUIFER", 4 successors

Direct hit scenario - "DIRECT", 4 successors

2.3.6 END NODES:

Stop after first site fails - "STOP1 "

Stop after second site fails - "STOP2 "

Stop after both sites fail - "STOP3 "

Call to deterministic model - "MODEL "

2.3.7 SPECIAL TERMINAL LOTTERIES (Y or N): Y

QUESTION NUMBER (0 TO EXIT): 6

print (Y or N): Y

plot (Y or N): Y

index (0 to quit): 2

index (0 to quit): 3

index (0 to quit): 4 [A maximum of 10 special

index (0 to quit): 5 lotteries can be run at one time.

index (0 to quit): 8 It will prompt the user for up

index (0 to quit): 9 to 11 indices, but the 11th

index (0 to quit): 10 response will always be set to

index (0 to quit): 11 zero.]

index (0 to quit): 12

index (0 to quit): 13

index (0 to quit): 0

2.3.8 QUESTION NUMBER (0 TO EXIT): 7

Endpoint path printout (Y or N): Y

index (0 to quit): 21

index (0 to quit): 22

index (0 to quit): 23 [A maximum of 10 path indices can

index (0 to quit): 24 be run at one time. It will

index (0 to quit): 25 prompt the user for up to 11

index (0 to quit): 26 indices, but the 11th response

index (0 to quit): 27 will always be set to zero.]

index (0 to quit): 28

index (0 to quit): 29

index (0 to quit): 30

index (0 to quit): 0

2.3.9 QUESTION NUMBER (0 TO EXIT): 10

Force successors (Y or N): Y

ENTER names of nodes followed by chosen successor

each on a separate line: [This forces which site is the
primary site choice.

end with a blank line

PRIMARY 1 1 for Gulf, 2 for Permian,
and 3 for Paradox.]

3.0 TERMINAL REWARD INDICES

3.1 MAIN LOTTERY (DISCOUNTED):

- 1 - Total equivalent dollar cost for all models

3.2 SPECIAL TERMINAL LOTTERIES:

3.2.1 Safety Outcomes (undiscounted, raw numbers) -

- 2 - Non-occupational fatalities
- 3 - Non-occupational injuries
- 4 - Occupational fatalities
- 5 - Occupational injuries
- 6 - Non-occupational acute effects
- 7 - Occupational acute effects
- 8 - Non-occupational somatic & genetic effects
- 9 - Occupational somatic & genetic effects

3.2.2 Cost Outcomes (discounted) -

- 10 - Total for cost model
- 11 - Repository cost
- 12 - Research & development cost
- 13 - Waste transportation cost
- 14 - Salt transportation cost

3.2.3 Community Outcomes (discounted) -

- 15 - Total community cost
- 16 - C & C cost

3.2.4 Environmental Outcomes (undiscounted, raw numbers) -

- 17 - Noise
- 18 - Visual
- 19 - Air quality

3.2.5 20 - Waste mix

- 1 - Spent fuel
- 2 - Reprocessing

- 3.2.6   21 - Primary site choice
            1 - Gulf
            2 - Permian
            3 - Paradox
- 3.2.7   22 - Secondary site choice
            1 - First possible other site
            2 - Second possible choice
                ie: If the primary choice is Permian,
                then secondary = 1 is Gulf and
                secondary = 2 is Paradox.
- 3.2.8   23 - Outcome of site characterization
            1 - Both sites acceptable
            2 - Primary acceptable, secondary not acceptable
            3 - Primary not acceptable, secondary acceptable
            4 - Both sites not acceptable
- 3.2.9   24 - Outcome of exploratory shaft
            1 - Build first remaining choice
            2 - Build second remaining choice
            3 - Build third remaining choice
                (Remaining choice means sites not eliminated by site
                characterizations.)
- 3.2.10   25 - Actual site of repository
            1 - Gulf
            2 - Permian
            3 - Paradox
- 3.2.11   26 - Preconstruction phase delay
            1 - Minimum value
            2 - Middle value
            3 - Maximum value
                (Varies by site)

- 3.2.12   27 - Construction phase delay
              1 - Minimum value
              2 - Maximum value
              (Varies by site)
- 3.2.12   28 - Labor people-years multiplier
              1 - Minimum value
              2 - Middle value
              3 - Maximum value
              (Varies by site)
- 3.2.13   29 - Labor hourly wage multiplier
              1 - Minimum value
              2 - Maximum value
              (Varies by site)
- 3.2.14   30 - Research & development cost multiplier
              1 - Minimum value
              2 - Maximum value
              (Varies by site)

4.0 GLOSSARY OF NODES USED IN GENTREE TO FORM TREE

- ABANDON - The branches from here represent the building of the repository at the current site or abandoning salt as a media. A chance node with two branches to BUILDPRIMARY & STOP1, or BUILDSECOND & STOP2, or BUILDTHIRD & STOP3.
- AQUIFER - This node has four branches which represent the four possible outcomes of the repository contaminating the aquifer. A chance node with four branches to DIRECTHIT.
- BUILDPRIMARY - This node represents placing the repository at the primary site. There is only one branch coming out of it, because it just sets SITEVAL to the appropriate value before calling PRECONDELAY. A chance node with one branch to PRECONDELAY.
- BUILDSECOND - This node represents placing the repository at the second site. There is only one branch coming out of it, because it just sets SITEVAL to the appropriate value before calling PRECONDELAY. A chance node with one branch to PRECONDELAY.
- BUILDTHIRD - This node represents placing the repository at the third site. There is only one branch coming out of it, because it just sets SITEVAL to the appropriate value before calling PRECONDELAY. A chance node with one branch to PRECONDELAY.
- CONDELAY - This node has two branches coming out of it which represent the two possible delays in the construction phase. A chance with two branches to OPERDELAY.

- DIRECTHIT - This node has four branches which represent the four possible outcomes of someone drilling directly into the repository. A chance node with four branches to GETOUTCOMES.
- GETOUTCOMES - This is the final node of the tree. It calls the deterministic model to get the reward values for the set of parameters corresponding to the path taken through the tree. It also sets the endpath values. A terminal node.
- LABORPPYEARS - This node has three branches which represent the three possible multipliers for the labor in manyears. A chance node with three branches to LABORWAGE.
- LABORWAGE - This node has two branches which represent the two possible multipliers for the labor hourly wage. A chance node with two branched to RNDCONSTMULT.
- MIXSCENARIO - The starting node of the tree. The branches out of this node represent the two possible waste mixes. A chance node with two branches going to PRIMARY.
- OPERDELAY - This node has one branch coming out of it which represents the one given delay in the operations phase. This node was written in so that various operations delays could be easily added later. A chance node with one branch to LABORPPYEARS.
- PRECONDELAY - This node has three branches coming out of it which represent the three possible delays in the preconstruction phase. A chance node with three branches to CONDELAY.
- PRIMARY - The branches out of this node represent the three possible primary site choices. A decision node with three branches going to SECONDARY.

- RNDCOSTMULT - This node has two branches which represent the two possible multipliers for the research & development costs. If no post-closure nodes are being run, it is a chance node with two branches to GETOUTOMES. Otherwise, it is a chance node with two branches to SOLUTIONMINE.
- SECONDARY - The branches out of this node represent the two possible secondary site choices. A decision node with two branches going to SITECHARACTER.
- SITECHARACTER - The branches out of here represent the four possible outcomes of the site characterizations on both the primary & secondary site choices. A chance node with four branches going to XSHAFTRESULT.
- SOLUTIONMINE - This node has four branches which represent the four possible outcomes of solution mining. A chance node with four branches to AQUIFER.
- STOP1 - This node represents abandoning salt after the primary site fails. A terminal node.
- STOP2 - This node represents abandoning salt after the second site fails. A terminal node.
- STOP3 - This node represents abandoning salt after the third site fails. A terminal node.
- XSHAFTRESULT - The branches from here represent the two possible outcomes from drilling the exploratory shaft. A chance node with two branches going to BUILDTHIRD & STOP3, if both sites were found unacceptable in SITECHARACTER, or going to ABANDON.

4.1 TOTAL NUMBER OF ENDNODES FOR EACH WASTE MIX SCENARIO:

Total Number of Endnodes = Number of model calls
+ number of internal stops

Number of model calls = (2 possible R&D Multipliers) *
(2 possible Hourly Wage Multipliers) *
(3 possible Labor in Man-Years Multipliers) *
(1 possible Operational Delay) *
(2 possible Construction Delays) *
(3 possible Preconstruction Delays) *
(7 possible Site Characterization/Exploratory
Shaft Result/Building choices) *
(2 possible Secondary Site choices) *
(3 possible Primary Site choices)

= 3024

Number of internal stops = (7 possible Site Characterization/Exploratory
Shaft Result/Building choices) *
(2 possible Secondary Site choices) *
(3 possible Primary Site choices)

= 42

Total Number of Endnodes = 3066

4.2 PROBABILITIES & REWARDS FOR EACH NODE

4.2.1 MIXSCENARIO NODE:

(for all sites)	*	Spent Fuel	p=1.0	r=0.0
		Reprocessing	p=0.0	r=0.0

4.2.2 SITECHARACTER NODE:

Gulf-1st Permian-2nd	*	Both ok	p=0.8585	r=0.0
		1st ok, 2nd not	p=0.0443	r=0.0
		1st not, 2nd ok	p=0.0925	r=0.0
		Both not ok	p=0.0047	r=0.0
Gulf-1st Paradox-2nd	*	Both ok	p=0.7839	r=0.0
		1st ok, 2nd not	p=0.1188	r=0.0
		1st not, 2nd ok	p=0.0845	r=0.0
		Both not ok	p=0.0128	r=0.0
Permian-1st Gulf-2nd	*	Both ok	p=0.8585	r=0.0
		1st ok, 2nd not	p=0.0925	r=0.0
		1st not, 2nd ok	p=0.0443	r=0.0
		Both not ok	p=0.0047	r=0.0
Permian-1st Paradox-2nd	*	Both ok	p=0.8285	r=0.0
		1st ok, 2nd not	p=0.1251	r=0.0
		1st not, 2nd ok	p=0.0426	r=0.0
		Both not ok	p=0.0065	r=0.0
Paradox-1st Gulf-2nd	*	Both ok	p=0.7839	r=0.0
		1st ok, 2nd not	p=0.0845	r=0.0
		1st not, 2nd ok	p=0.1188	r=0.0
		Both not ok	p=0.0128	r=0.0
Paradox-1st Permian-2nd	*	Both ok	p=0.8258	r=0.0
		1st ok, 2nd not	p=0.0426	r=0.0
		1st not, 2nd ok	p=0.1251	r=0.0
		Both not ok	p=0.0065	r=0.0

4.2.3 XSHAFTRESULT NODE:

1st and/or 2nd ok

Gulf	*	Shaft ok	p=0.9997	r=0.0
		Shaft not ok	p=0.0003	r=-100.0
Permian	*	Shaft ok	p=0.9894	r=0.0
		Shaft not ok	p=0.0106	r=-100.0
Paradox	*	Shaft ok	p=0.9932	r=0.0
		Shaft not ok	p=0.0068	r=-100.0

Both not acceptable -

For all sites	*	Shaft ok	p=1.0	r=0.0
		Shaft not ok	p=0.0	r=-100.0
		(* this forces abandoning salt as a media)		

4.2.4 ABANDON NODE:

For all sites	*	Build site	p=1.0	r=0.0
		Abandon salt as a media	p=0.0	r=-100.0

4.2.5 PRECONDELAY NODE:

Gulf	*	0 year delay	p=0.33	r=0.0
		1 year delay	p=0.34	r=0.0
		2 year delay	p=0.33	r=0.0
Permian	*	0 year delay	p=0.50	r=0.0
		1 year delay	p=0.50	r=0.0
		2 year delay	p=0.00	r=0.0

Paradox	*	0 year delay	p=0.50	r=0.0
		1 year delay	p=0.50	r=0.0
		2 year delay	p=0.00	r=0.0

4.2.6 CONDELAY NODE:

Gulf	*	0 year delay	p=0.55	r=0.0
		1 year delay	p=0.45	r=0.0
Permian	*	0 year delay	p=0.39	r=0.0
		1 year delay	p=0.61	r=0.0
Paradox	*	0 year delay	p=0.38	r=0.0
		1 year delay	p=0.62	r=0.0

4.2.7 LABORPPYEARS NODE: (MULTIPLIER ON LABOR IN PEOPLE-YEARS)

Gulf	*	1.0	p=0.33	r=0.0
		1.2	p=0.33	r=0.0
		1.5	p=0.34	r=0.0
Permian	*	1.0	p=0.33	r=0.0
		1.2	p=0.33	r=0.0
		1.5	p=0.34	r=0.0
Paradox	*	1.0	p=0.33	r=0.0
		1.2	p=0.33	r=0.0
		1.5	p=0.34	r=0.0

4.2.8 LABORWAGE NODE: (MULTIPLIER ON LABOR WAGES)

Gulf	*	0.84	$p=0.50$	$r=0.0$
		1.12	$p=0.50$	$r=0.0$
Permian	*	0.84	$p=0.50$	$r=0.0$
		1.12	$p=0.50$	$r=0.0$
Paradox	*	0.84	$p=0.50$	$r=0.0$
		1.12	$p=0.50$	$r=0.0$